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| Last Name | First Name | Middle Initial | Residence (City And Either State Or Foreign Country) | |
| Fischetti Schuch | Vincent Raymond | | West Hempstead, New York New York, New York | |
| TITLE OF INVENTION (280 characters max) | | | | |
| Lytic Enzymes and Spore Surface Antigen for Detection and Treatment of <i>Bacillus Anthracis</i> Bacteria and Spores | | | | |
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Respectfully submitted,

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**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
PROVISIONAL APPLICATION FOR UNITED STATES LETTERS PATENT**

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TITLE:

LYTIC ENZYMES AND SPORE SURFACE
ANTIGEN FOR DETECTION AND TREATMENT
OF *BACILLUS ANTHRACIS* BACTERIA AND
SPORES

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**LYTIC ENZYMES AND SPORE SURFACE ANTIGEN FOR DETECTION AND TREATMENT OF
BACILLUS ANTHRACIS BACTERIA AND SPORES**

FIELD OF THE INVENTION

5 **[01]** The present invention relates to the identification and characterization of environmental bacteriophages infecting *Bacillus anthracis*. Specifically, the invention relates to the isolated sequences for the gamma (γ)-phage and the W-phage of *B. anthracis*, nucleic acids of each genome, nucleic acids comprising nucleotide sequences of open reading frames (ORF's) of its genome, and polypeptides encoded by the nucleic
10 acids.

BACKGROUND

[02] Anthrax is a disease caused by the spore-forming bacterium, *Bacillus anthracis*, a bacterium that is readily found in soil, *B. anthracis* primarily causes disease in plant-eating animals. Anthrax infection of humans is infrequent (1 in
15 100,000). When humans do become infected, they usually acquire the bacterium from contact with infected animals, animal hides or hair, or animal feces. The human disease has a relatively short incubation period (less than a week) and usually progresses rapidly to a fatal outcome.

[03] In humans, anthrax may occur in three different forms: coetaneous anthrax, gastrointestinal anthrax and inhalation anthrax. Coetaneous anthrax, the most common
20 form in humans, is usually acquired when the bacterium, or spores of the bacterium, enter the body through an abrasion or cut on the skin. The bacteria multiply at the site of the abrasion, cause a local edema, and a series of skin lesions--papule, vesicle, pustule and necrotic ulcer--are sequentially produced. Lymph nodes nearby the site are
25 eventually infected by the bacteria and, in cases where the organisms then enter the bloodstream (20% of cases), the disease is often fatal. Gastrointestinal anthrax is caused by eating contaminated meat. Initial symptoms include nausea, vomiting and fever. Later, infected individuals present with abdominal pain, severe diarrhea and vomiting of blood. This type of anthrax is fatal in 25% to 60% of cases. Inhalation anthrax (also
30 called woolsorters' disease) is acquired through inhalation of the bacteria or spores.

Initial symptoms are similar to those of a common cold. Symptoms then worsen and these individuals present with high fever, chest pain and breathing problems. The infection normally progresses systemically and produces a hemorrhagic pathology. Inhalation anthrax is fatal in almost 100% of cases.

5 [04] *B. anthracis* possesses two major virulence components. The first virulence component is a polysaccharide capsule which contains poly-D-glutamate polypeptide. The poly-D-glutamate capsule is not itself toxic but plays an important role in protecting the bacterium against anti-bacterial components of serum and phagocytic engulfment. As the *B. anthracis* bacterium multiplies in the host, it produces a secreted
10 toxin which is the second virulence component of the organism. This anthrax toxin mediates symptoms of the disease in humans.

[05] The anthrax toxin is comprised of three distinct proteins encoded by the bacterium, called protective antigen (PA), lethal factor (LF) and edema factor (EF). PA is the component of the anthrax toxin that binds to host cells using an unidentified cell-
15 surface receptor. Once it binds to cell surfaces, EF or LF may subsequently interact with the bound PA. The complexes are then internalized by the host cell with significant effects. EF is an adenylate cyclase which causes deregulation of cellular physiology, resulting in edema. LF is a metalloprotease that cleaves specific signal transduction molecules within the cell (MAP kinase isoforms), causing deregulation of
20 said pathways, and cell death. Injection of PA, LF or EF alone, or LF in combination with EF, into experimental animals produces no effects. However, injection of PA plus EF produces edema. Injection of PA plus LF is lethal, as is injection of PA plus EF plus LF.

[06] As an acute, febrile disease of virtually all warm-blooded animals, including
25 man, anthrax has been used in biological weapons. For example, ten grams of anthrax spore may kill as many people as a ton of the chemical warfare agent, sarin. Terrorists have included dry spores in letters to target specific individuals for harassment. Biological weapons of mass destruction have been developed that contain large quantities of anthrax spores for release over enemy territory. Once released, spores
30 contaminate a wide geographical area, infecting nearly all susceptible mammals. Due to the spore's resistance to heat and dry conditions, contaminated land may remain a

danger for years. In view of the serious threat posed by the disease, effective diagnostic tools are needed to assist in prevention and control of natural and man-made outbreaks. Due to the highly lethal nature of anthrax and BW agents in general, there is great need for the development of sensitive and rapid BW agent detection. Current detection
5 technology for biological warfare agents have traditionally relied on time-consuming laboratory analysis or onset of illness among people exposed to the BW agent.

[07] Coetaneous anthrax is acquired via injured skin or membranes, entry sites where the spore germinate into vegetative cells. Proliferation of vegetative cells results in gelatinous edema. Alternatively, inhalation of the spores results in high fever and
10 chest pain. Both types may be fatal unless the invasive aspect of the infection may be intercepted.

[08] One promising approach to the detection and treatment of *B. anthracis* is the use of bacteriophage lysins as bacteriolytic agents. Bacteriophages specific for *B. anthracis* and related *B. cereus* bacteria strains may be isolated and used to detect and
15 treat these bacteria. Bacteriophages near *B. anthracis* spores during spore germination may be used to infect and lyse the bacteria. A variety of phage-based bacterial therapies have been reviewed. D.H. Duckworth, P.A. Gulig, "Bacteriophages: Potential treatment for bacterial infections," *BioDrugs*, 16(1), 57-62 (2002). There are various environmental bacteriophages present in soils that may infect and lyse *B. anthracis*
20 under controlled conditions. H.W. Ackermann, et al., "New Bacillus bacteriophage species," *Archives of Virology*, 135(3-4), 333-344 (1994); H.W. Ackerman, M.S. Dubrow, *Viruses of prokaryotes: General properties of bacteriophages*, Boca Raton, FL, CRC Press, Inc. (1989);

[09] A bacterial lysin PlyG from bacteriophage- γ of *B. anthracis* has been shown
25 to lyse vegetative *B. anthracis* cells and relates to promising methods for treatment of anthrax. R. Schuch, D. Nelson, V. Fischetti, "A bacteriolytic agent that detects and kills *Bacillus anthracis*," *Nature* 418, 884-889 (2002). A nucleotide sequence encoding PlyG is disclosed in GenBank accession #AF536823 and has a molecular mass of about 27,000. PlyG has been shown to control anthrax disease in mice, and to bind to
30 vegetative cells. However, PlyG has no means to replicate itself in the presence of host

bacteria. Methods and composition for the treatment of a variety of bacterial infections using a phage associated lytic enzyme specific for the invasive bacteria and an appropriate carrier for delivering the lytic enzyme into a patient are discussed in the following U.S. Patents issued to Fischetti et al.: 5,604,109; 5,985,271; 6,056,954; 6,056,955 6,248,324; 6,254,866; and 6,264,945. Walter reports the effective treatment of 14 of 24 virulent *B. anthracis* strains by phage based methods in a preliminary study done at Johns Hopkins University Applied Physics Laboratory. Michael Walter, Ph.D., "Efficacy and Durability of *Bacillus anthracis* Bacteriophages Used Against Spores," *Journal of Environmental Health*, July/August 2003, 9-15.

[10] Bacteriophages for *B. anthracis* may be isolated from the environment. For instance, Walter et al. report the isolation of Phages Nk, DB and MH for *B. anthracis* in topsoil. Walter, MH, Baker, DD, "Three *Bacillus anthracis* bacteriophages from topsoil," *Curr Microbiol.* 2003 Jul; 47(1): 55-58. Further bacteriophages useful for detection and treatment of *B. anthracis* are reported herein. The W and γ environmental bacteriophages of *B. anthracis* have been identified in topsoil, but the isolation of the polynucleotide and the identification of open reading frames coding for various polypeptides therein were unknown. E.W. McCloy, "Studies of a lysogenic *Bacillus* strain. I. A bacteriophage specific for *Bacillus anthracis*," *Journal of Hygiene*, 49(1), 114-125 (1951); E.R. Brown, W.B. Cherry, "Specific identification of *Bacillus anthracis* by means of a variant bacteriophage," *Journal of Infectious Diseases*, 96(1), 34-39 (1955).

[11] The direct introduction of bacteriophages into an animal to prevent or fight diseases has certain drawbacks. Specifically, both the bacteria and the phage have to be in the correct and synchronized growth cycles for the phage to attach. Additionally, there must be the right number of phages to attach to the bacteria; if there are too many or too few phages, there will be either no attachment or no production of the lysing enzyme. The phage must also be active enough. The phages are also inhibited by many things including bacterial debris from the organism it is going to attack. Further complicating the direct use of a bacteriophage to treat bacterial infections is the possibility of immunological reactions within the subject being treated, potentially

rendering the phage non-functional. The ability of bacteriophages to lyse and kill target bacterial may also be decreased by sunlight, UV light, desiccation or other conditions encountered during storage or use of a phage-containing therapeutic agent. Therefore, the potential effectiveness of any given bacteriophage against a target bacteria depends
5 on the conditions under which the phage is deployed against the target bacteria.

Studying the structure of phages and their efficacy against target bacteria in various conditions are essential to developing therapeutic methods for treating and preventing disease caused by target bacteria. Investigations of the structure and function of phages may also relate to diagnostic methods for detecting target bacteria and spores, such as
10 those of *B. anthracis*. Given the host of environmental conditions that may alter the effectiveness of a phage such as phage W and phage- γ against a *B. anthracis* or related target bacteria, the isolation and analysis of the polynucleotide sequences, and associated polypeptide sequences, of these and other phages are needed to relate to effective methods for prevention, treatment and diagnosis of *B. anthracis* bacteria and
15 spores.

SUMMARY

[12] The invention relates to two bacteriophages of *B. anthracis*, bacteriophage gamma (γ) and bacteriophage W, which may be isolated from their native environment
20 or recombinantly produced. Applicants have isolated and characterized various bacteriophages active against *B. anthracis*.

[13] The present invention provides, among other things, the γ and W bacteriophages for *B. anthracis*, the nucleic acid sequence of these bacteriophage genomes, as well as portions of the nucleic acid sequence of the bacteriophage genome
25 (*e.g.*, a portion containing an open reading frame), and proteins encoded by the nucleic acid sequences, as well as nucleic acid constructs comprising portions of the nucleic acid sequence of the bacteriophage genome, and host cells comprising such nucleic acid constructs.

[14] The invention additionally relates to the nucleic acids of the genome of
30 bacteriophages γ and W, as well as to the nucleic acids of portions of the genome of

bacteriophages γ and W; to isolated nucleic acid molecules containing a nucleotide sequence of an open reading frame (or more than one open reading frame) of the genomes of bacteriophages γ and W; to isolated nucleic acid molecules encoding a polypeptide obtainable from bacteriophages γ and W or an active derivative or fragment of the polypeptide (e.g., a DNA polymerase, such as a DNA polymerase lacking exonuclease domains; a 3'-5' exonuclease, such as a 3'-5' exonuclease lacking DNA polymerase domain; a 5'-3' exonuclease (RNase H); a DNA helicase; or an RNA ligase); to DNA constructs containing the isolated nucleic acid molecule operatively linked to a regulatory sequence; and also to host cells comprising the DNA constructs.

10 The invention further relates to isolated polypeptides encoded by these nucleic acids, as well as active derivatives or fragments of the polypeptides.

[15] In particular embodiments, the present invention relates to an isolated nucleic acid sequences that are at least 60%, 70%, 80%, 90%, 95%, 97%, 98-100% or 100% identical to a polynucleotide sequences encoded by SEQ ID NO:1, SEQ ID

15 NO:2, SEQ ID NO:110, SEQ ID NO:111, SEQ ID NO:112 or SEQ ID NO:113 and to a polynucleotide sequence encoding a polypeptide selected from SEQ ID NO:3- SEQ ID NO:109. In other embodiments, the polynucleotide of the invention is an isolated nucleic acid consisting of the sequence of SEQ ID NO:1 or SEQ ID NO:2, and an open reading frame (ORF) portion therein as identified in Table 1 or Table 2 below. The

20 invention relates to an isolated nucleic acid sequence of SEQ ID NO:1, an open reading frame of SEQ ID NO:1 set forth in Table 1, SEQ ID NO:2, or an open reading frame of SEQ ID NO:2 set forth in Table 2, with up to 5, 10, 20, 30, 40, 50, 60, 80, 100 or more conservative nucleic acid substitutions. Further provided are nucleic acid sequences of SEQ ID NO:110, SEQ ID NO:111, SEQ ID NO:112 or SEQ ID NO:113 with up to 5,

25 10 or 20 conservative nucleic acid substitutions. The invention also relates to an isolated nucleic acid molecule comprising 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 or more contiguous nucleotides of SEQ ID NO:1 or SEQ ID NO:2. Other embodiments relate to an isolated nucleic acid molecule comprising contiguous nucleotides of an open reading frame from SEQ ID NO:1 or SEQ ID NO:2. Still other embodiments

30 relate to a DNA construct comprising an isolated nucleic acid molecule comprising the

nucleotide sequence of an open reading frame SEQ ID NO:1 or SEQ ID NO:2, operatively linked to a regulatory sequence, or the nucleic acid sequences of SEQ ID NO:110, SEQ ID NO:111, SEQ ID NO:112 or SEQ ID NO:113.

[16] The invention further relates to a polypeptide comprising a polypeptide sequence selected from SEQ ID NO:3- SEQ ID NO:109. Some embodiments relate to a purified polypeptide, the amino acid sequence of which comprises a sequence at least 60%, 70%, 80%, 90%, 95%, 97%, 98-100% or 100% identical to a polypeptide sequence selected from SEQ ID NO:3- SEQ ID NO:109. Also provided is an isolated nucleic acid sequence encoding a polypeptide comprising the amino acid sequence set forth in a polypeptide sequence selected from SEQ ID NO:3- SEQ ID NO:109, with up to 5, 10, 20, 30, 40, 50, 60, 80, 100 or more conservative amino acid substitutions. The invention also relates to a purified polypeptide, the amino acid sequence of which consists of a polypeptide sequence selected from SEQ ID NO:3- SEQ ID NO:109. Other embodiments of the invention relate to a purified polypeptide, the amino acid sequence of which is encoded by an open reading frame from SEQ ID NO:1 or SEQ ID NO:2.

[17] The invention relates to polypeptides encoded by SEQ ID NO:1 or SEQ ID NO:2 that are able to infect *B. anthracis* or RSVF1 bacteria. Particular embodiments relate to polypeptide sequences that infect *B. anthracis* or RSVF1 to a greater extent than other *B. cereus* bacteria. For example, some polypeptides of the invention may bind to *B. cereus* bacteria other than *B. anthracis* or RSVF1 at less than 100 plaque forming units/ml (PFU/ml), or even less than 10 PFU/ml, or less than 1 PFU/ml. In one embodiment, the invention relates to polypeptides encoded by SEQ ID NO:1 or SEQ ID NO:2 that are able to specifically bind to *B. anthracis* or RSVF1. The nucleic acid may encode one or more polypeptides that are able to infect *B. anthracis*. The nucleic acid may also encode one or more polypeptides that are able to bind to the surface of *B. anthracis*. The nucleic acid may also encode one or more polypeptides that exhibit fosfomycin resistance. The nucleic acid may encode one or more polypeptides that are spore surface antigens of *B. anthracis*.

[18] In one embodiment, the invention relates to a polypeptide encoded by the ORF 14 portion of SEQ ID NO:1, the polypeptide of SEQ ID NO:29, the polypeptide

encoded by the ORF 14 portion of SEQ ID NO:2, or the polypeptide of SEQ ID NO:30, wherein the polypeptide is able to bind to the surface of *B. anthracis*. In another embodiment, the invention relates to a polypeptide encoded by the ORF17 portion of SEQ ID NO:1, the polypeptide of SEQ ID NO:35, the polypeptide encoded by the ORF 17 portion of SEQ ID NO:2, or the polypeptide of SEQ ID NO:36, wherein the polypeptide kills *B. anthracis*. In yet another embodiment, the invention relates to a polypeptide encoded by the ORF 41 portion of SEQ ID NO:1, or the polypeptide of SEQ ID NO:83, wherein the polypeptide exhibits Fosfomycin resistance. In further embodiments, the invention relates to the polypeptide encoded by the ORF 39 portion of SEQ ID NO:2, or the polypeptide of SEQ ID NO:82, wherein the polypeptide is a surface antigen of *B. anthracis*.

[19] Further provided are isolated nucleic acids that hybridize under high stringency conditions to the sequence of SEQ ID NO:1, SEQ ID NO:2, or open reading frame portions thereof as detailed in Table 1 and Table 2. In one embodiment, the invention relates to an isolated nucleic acid that hybridizes under high stringency conditions to a nucleic acid encodes a polypeptide that comprises a polypeptide sequence selected from SEQ ID NO:3- SEQ ID NO:109.

[20] Also provided is an isolated nucleic acid that hybridizes under high stringency conditions to the sequence of the ORF 14 from SEQ ID NO:1, or the ORF 14 from SEQ ID NO:2, wherein said nucleic acid encodes a polypeptide that is able to bind to the surface of *B. anthracis*. Further provided is an isolated nucleic acid that hybridizes under high stringency conditions to the sequence of the ORF 17 from SEQ ID NO:1, or the ORF 17 from SEQ ID NO:2, wherein said nucleic acid encodes a polypeptide that is kills *B. anthracis*. Further provided is an isolated nucleic acid that hybridizes under high stringency conditions to the sequence of the ORF 41 from SEQ ID NO:1, wherein said nucleic acid encodes a polypeptide exhibits Fosfomycin resistance. Also provided is an isolated nucleic acid that hybridizes under high stringency conditions to the sequence of the ORF 39 from SEQ ID NO:2, wherein said nucleic acid is a spore surface antigen of *B. anthracis*.

[21] Further provided are expression vectors comprising the nucleic acid sequence associated with ORF 14 from SEQ ID NO:1, the ORF 14 from SEQ ID

NO:2, the ORF 17 from SEQ ID NO:1, the ORF 17 from SEQ ID NO:2, the ORF 41 from SEQ ID NO:1 or the ORF 39 from SEQ ID NO:2, operably associated with a promoter, and associated host cells comprising these vectors. Further provided are methods for preparing a polypeptide, each method comprising the step of culturing the host cell comprising the nucleotide sequence associated with ORF 14 from SEQ ID NO:1, the ORF 14 from SEQ ID NO:2, the ORF 17 from SEQ ID NO:1, the ORF 17 from SEQ ID NO:2, the ORF 41 from SEQ ID NO:1 or the ORF 39 from SEQ ID NO:2, under conditions that permit expression of the polypeptide from the expression vector, and isolating the polypeptide from the host cell. The invention also relates to an isolated nucleic acid comprising a sequence that hybridizes under high stringency conditions to a hybridization probe, the nucleotide sequence of which comprises or consists of ORF 14 from SEQ ID NO:1, the ORF 14 from SEQ ID NO:2, the ORF 17 from SEQ ID NO:1, the ORF 17 from SEQ ID NO:2, the ORF 41 from SEQ ID NO:1 or the ORF 39 from SEQ ID NO:2, or the complements thereof. Further provided is an isolated nucleic acid comprising a sequence that hybridizes under high stringency conditions to a hybridization probe, the nucleotide sequence of which encodes the protein of a polypeptide sequence encoded by the ORF 14 from SEQ ID NO:1, the ORF 14 from SEQ ID NO:2, the ORF 17 from SEQ ID NO:1, the ORF 17 from SEQ ID NO:2, the ORF 41 from SEQ ID NO:1 or the ORF 39 from SEQ ID NO:2, or the nucleotide sequence of which encodes the protein encoded by these ORFs.

[22] Other embodiments of the instant invention include an isolated nucleic acid comprising a sequence that hybridizes under high stringency conditions to a hybridization probe, the nucleotide sequence of which consists of an open reading frame from SEQ ID NO:1 from Table 1, an open reading frame from SEQ ID NO:2 from Table 2, SEQ ID NO:110, SEQ ID NO:111, SEQ ID NO:112 or SEQ ID NO:113 or the complements thereof. The invention also relates to an isolated nucleic acid comprising a sequence that hybridizes under high stringency conditions to a hybridization probe, the nucleotide sequence of which encodes the protein of a polypeptide sequence selected from SEQ ID NO:3- SEQ ID NO:109.

[23] The invention further relates to an expression vector comprising the nucleic acid sequence of SEQ ID NO:1 or SEQ ID NO:2 or an open reading frame thereof as

noted in Table 1 or Table 2, operably associated with a promoter, or a host cell comprising said vector. The invention also relates to an isolated nucleic acid comprising a sequence that encodes a protein of a polypeptide sequence selected from SEQ ID NO:3- SEQ ID NO:109, operably associated with a promoter, or a host cell comprising said vector.

[24] The invention also relates to methods for preparing a polypeptide, the method comprising the step of culturing the host cell under conditions that permit expression of the polypeptide from the expression vector, and isolating the polypeptide from the host cell.

[25] The invention also relates to methods of screening for a compound that binds to a polypeptide, the method comprising: providing the nucleic acid of an open reading frame from SEQ ID NO:1 or SEQ ID NO:2, or an isolated nucleic acid comprising a sequence that encodes a protein of a polypeptide sequence selected from SEQ ID NO:3- SEQ ID NO:109, and introducing the nucleic acid into a cell and allowing the cell to produce the polypeptide encoded by the nucleic acid, contacting a test compound with the polypeptide, and determining whether the test compound has bound to the polypeptide.

[26] The invention also relates to a method of screening for a compound that binds to a polypeptide, the method comprising: providing the nucleic acid encoding the polypeptide selected from the group consisting of: SEQ ID NO:3 – SEQ ID NO:109, introducing the nucleic acid into a cell and allowing the cell to produce the polypeptide encoded by the nucleic acid, contacting a test compound with the polypeptide, and determining whether the test compound has bound to the polypeptide.

BRIEF DESCRIPTION OF THE DRAWINGS

[27] **FIGURES. 1A-1B** (FIG. 1A, FIG. 1B) show the nucleotide (FIG. 1A; SEQ ID NO:1) and amino acid (FIG. 1B) sequences of *Bacillus anthracis* bacteriophage-γ.

[28] **FIGURES. 2A-2B** show the nucleotide (FIG. 1A; SEQ ID NO:2) and amino acid (FIG. 1B) sequences of *Bacillus anthracis* bacteriophage-W.

[29] **FIGURE 3A** is an electron microscope view of the page- γ . **FIGURE 3B** is an electron micrograph of page- γ particles adhered to cellular debris via the tips of the tail fibers. **FIGURE 3C** is an electron micrograph showing induction of unusual ring-shaped colonies of *B. cereus* strain ATCC 11950 with phage-W in the presence of fosfomyin. **FIGURE 3D** is an electron micrograph showing absence of ring-shaped colonies of *B. cereus* strain ATCC 11950 with phage-W in the absence of fosfomyin.

[30] **FIGURE 4A** and **FIGURE 4B** show analysis of the *Bacillus anthracis* genome (FIG. 4A) compared with other *Bacillus spp.* and *Clostridium* (FIG. 4B). **FIGURE 4C** is a graph showing results from the introduction of the pDG148::pg41 clone into RSVF1 has resulted in a 4-log increase in resistance to the antibiotic fosfomycin.

[31] **FIGURE 5A** shows a comparison of the genomic sequences of both γ and W by pair wise comparison. **FIGURE 5B** is a schematic of the *Bacillus anthracis* genome. **FIGURE 5C** is a schematic showing an alignment of the W phage.

[32] **FIGURE 6A** is a micrograph showing GFP-PlyG – binding of *Bacillus anthracis* in a whole cell manner. **FIGURE 6B** is a micrograph showing GFP-PlyG – binding of RSVF1 at only a polar positions. **FIGURE 6C** is a micrograph showing GFP-PlyG – binding of rare RSVF1 derivatives that bind in a whole cell fashion. **FIGURE 6D** is a micrograph showing GFP-Gp14 – whole cell binding with *Bacillus anthracis*. **FIGURE 6E** is a micrograph showing GFP-Gp14 – polar cell binding with *Bacillus anthracis*. **FIGURE 6F** is a micrograph showing *Bacillus anthracis* lysogenized with W becomes polar. **FIGURE 6G** and **FIGURE 6H** are micrographs showing fluorescence of GFP-PlyG binding to *Bacillus anthracis*.

[33] **FIGURE 7A** and **FIGURE 7B** are micrographs showing the effects of lvsogeny with W on RSVF1 and *B. anthracis* showing rod shape formation. **FIGURE 7C**, **FIGURE 7D**, **FIGURE 7E**, and **FIGURE 7F** are electron micrographs showing spore appearance by SEM under various conditions as described below.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[34] The invention relates to the identification and characterization of an environmental bacteriophage infecting both *B. anthracis* and a transition state *B. cereus*

strain, and thus establishing a means for genetic exchange between the two. Lysogeny of either organism exerts profound phenotypic changes and with *B. anthracis*, involves the acquisition of *B. cereus*-like features.

5 [35] A definition of terms used and their applicability to the disclosure are provided as follows:

[36] In this context of the embodiments, the term "lytic enzyme genetically coded for by a bacteriophage" means a polypeptide having at least some lytic activity against the host bacteria. The polypeptide has a sequence that encompasses a native sequence of a lytic enzyme and variants thereof. The polypeptide may be isolated from a variety
10 of sources, such as from phage, or prepared by recombinant or synthetic methods, such as those by Garcia et al. Every polypeptide has two domains. One domain is a choline binding portion at the carboxyl terminal side and the other domain is an amidase activity that acts upon amide bonds in the peptidoglycan at the amino terminal side. Generally speaking, a lytic enzyme according to the disclosure is between 25,000 and
15 35,000 daltons in molecular weight and comprises a single polypeptide chain; however, this may vary depending on the enzyme chain. The molecular weight most conveniently is determined by assay on denaturing sodium dodecyl sulfate gel electrophoresis and comparison with molecular weight markers.

[37] The term "purified" means that the biological material has been measurably
20 increased in concentration by any purification process, including by not limited to, column chromatography, HPLC, precipitation, electrophoresis, etc., thereby partially, substantially or completely removing impurities such as precursors or other chemicals involved in preparing the material. Hence, material that is homogenous or substantially homogenous (e.g., yields a single protein signal in a separation procedure such as
25 electrophoresis or chromatography) is included within the meanings of isolated and purified. Skilled artisans will appreciate that the amount of purification necessary will depend upon the use of the material. For example, compositions intended for administration to humans ordinarily must be highly purified in accordance with regulatory standards.

30 [38] "A native sequence phage associated lytic enzyme" is a polypeptide having the same amino acid sequence as an enzyme derived from nature. Such native

sequence enzyme may be isolated from nature or may be produced by recombinant or synthetic means. The term "native sequence enzyme" specifically encompasses naturally occurring forms (e.g., alternatively spliced or modified forms) and naturally-occurring variants of the enzyme. In one embodiment of the disclosure, the native
5 sequence enzyme is a mature or full-length polypeptide that is genetically coded for by a gene from a bacteriophage specific for *Bacillus anthracis*. Of course, a number of variants are possible and known, as acknowledged in publications such as Lopez et al., Microbial Drug Resistance 3: 199-211 (1997); Garcia et al., Gene 86: 81-88 (1990); Garcia et al., Proc. Natl. Acad. Sci. USA 85: 914-918 (1988); Garcia et al., Proc. Natl.
10 Acad. Sci. USA 85: 914-918 (1988); Garcia et al., Streptococcal Genetics (J.J. Ferretti and Curtis eds., 1987); Lopez et al., FEMS Microbiol. Lett. 100: 439-448 (1992); Romero et al., J. Bacteriol. 172: 5064-5070 (1990); Ronda et al., Eur. J. Biochem. 164: 621-624 (1987) and Sanchez et al., Gene 61: 13-19 (1987). The contents of each of these references, particularly the sequence listings and associated text that compares the
15 sequences, including statements about sequence homologies, are specifically incorporated by reference in their entireties.

[39] "A variant sequence phage associated lytic enzyme" means a functionally active lytic enzyme genetically coded for by a bacteriophage specific for *Bacillus anthracis*, as defined below, having at least 50%, 55%, 60%, 65%, 70%, 75%, 80%,
20 85%, 90%, 95%, 97%, 98%, 99%, or even at least 99.5% sequence identity with the amino acid or polynucleotide sequences shown below, or portions thereof. Of course a skilled artisan readily will recognize portions of this sequence that are associated with functionalities such as binding, and catalyzing a reaction. Polypeptide sequences and nucleic acids that encode these sequences are contemplated by some embodiments that
25 comprise at least 75%, 80%, 85%, 90%, 95%, 97%, 98%, 99% or more of each functional domain or open reading frame from the sequences provided herein. Such portions of the total sequence are very useful for diagnostics as well as therapeutics/prophylaxis. In fact, sequences as short as 5 amino acids long have utility as epitopic markers for the phage. More desirably, larger fragments or regions of
30 protein having a size of at least 8, 9, 10, 12, 15 or 20 amino acids, and homologous sequences to these, have epitopic features and may be used either as small peptides or

as sections of larger proteins according to embodiments. Nucleic acids corresponding to these sequences also are contemplated.

[40] Such phage associated lytic enzyme variants include, for instance, lytic enzyme polypeptides wherein one or more amino acid residues are added, or deleted at the N or C terminus of the sequences provided. In an embodiment one or more amino acids are substituted, deleted, and/or added to any position(s) in the sequence, or sequence portion. Ordinarily, a phage associated lytic enzyme will have at least about (e.g. exactly) 50%, 55%, 60%, 65%, 70%, 75%, amino acid sequence identity with native phage associated lytic enzyme sequences, more preferably at least about (e.g. exactly) 80%, 85%, 90%, 95%, 97%, 98%, 99% or 99.5% amino acid sequence identity. In other embodiments a phage associated lytic enzyme variant will have at least about 50% (e.g. exactly 50%) , 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 97%, 98%, 99%, or even at least 99.5% amino acid sequence identity with the sequences provided, or portions thereof.

[41] A polypeptide or amino acid “selected from SEQ ID NO:3– SEQ ID NO:109” refers to a polypeptide sequence selected from the group consisting of: SEQ ID NO:3, SEQ ID NO:4, SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:8, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:12, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:16, SEQ ID NO:17, SEQ ID NO:18, SEQ ID NO:19, SEQ ID NO:20, SEQ ID NO:21, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:25, SEQ ID NO:26, SEQ ID NO:27, SEQ ID NO:28, SEQ ID NO:29, SEQ ID NO:30, SEQ ID NO:31, SEQ ID NO:32, SEQ ID NO:33, SEQ ID NO:34, SEQ ID NO:35, SEQ ID NO:36, SEQ ID NO:37, SEQ ID NO:38, SEQ ID NO:39, SEQ ID NO:40, SEQ ID NO:41, SEQ ID NO:42, SEQ ID NO:43, SEQ ID NO:44, SEQ ID NO:45, SEQ ID NO:46, SEQ ID NO:47, SEQ ID NO:48, SEQ ID NO:49, SEQ ID NO:50, SEQ ID NO:51, SEQ ID NO:52, SEQ ID NO:53, SEQ ID NO:54, SEQ ID NO:55, SEQ ID NO:56, SEQ ID NO:57, SEQ ID NO:58, SEQ ID NO:59, SEQ ID NO:60, SEQ ID NO:61, SEQ ID NO:62, SEQ ID NO:63, SEQ ID NO:64, SEQ ID NO:65, SEQ ID NO:66, SEQ ID NO:67, SEQ ID NO:68, SEQ ID NO:69, SEQ ID NO:70, SEQ ID NO:71, SEQ ID NO:72, SEQ ID NO:73, SEQ ID NO:74, SEQ ID NO:75, SEQ ID NO:76, SEQ ID NO:77, SEQ ID NO:78, SEQ ID

NO:79, SEQ ID NO:80, SEQ ID NO:81, SEQ ID NO:82,SEQ ID NO:83, SEQ ID NO:84, SEQ ID NO:85, SEQ ID NO:86, SEQ ID NO:87, SEQ ID NO:88, SEQ ID NO:89, SEQ ID NO:90, SEQ ID NO:91, SEQ ID NO:92,SEQ ID NO:93, SEQ ID NO:94, SEQ ID NO:95, SEQ ID NO:96, SEQ ID NO:97, SEQ ID NO:98, SEQ ID NO:99, SEQ ID NO:100, SEQ ID NO:101, SEQ ID NO:102,SEQ ID NO:103, SEQ ID NO:104, SEQ ID NO:105, SEQ ID NO:106, SEQ ID NO:107, SEQ ID NO:108, and SEQ ID NO:109.

[42] "Percent amino acid sequence identity" with respect to the phage associated lytic enzyme sequences identified herein is defined as the percentage of amino acid residues in a candidate sequence that are identical with the amino acid residues in the phage associated lytic enzyme sequence, after aligning the sequences in the same reading frame and introducing gaps, if necessary, to achieve the maximum percent sequence identity, and not considering any conservative substitutions as part of the sequence identity. Alignment for purposes of determining percent amino acid sequence identity may be achieved in various ways that are within the skill in the art, such as using publicly available computer software such as blast software. Those skilled in the art may determine appropriate parameters for measuring alignment, including any algorithms needed to achieve maximal alignment over the whole length of the sequences being compared.

[43] In each case, of course conservative amino acid substitutions also may be made simultaneously in determining percent amino acid sequence identity. For example, a 15 amino acid long region of protein may have 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 97%, 98%, or 99% sequence homology with a polypeptide sequence selected from SEQ ID NO:3- SEQ ID NO:109, or portions thereof. At the same time, the 15 amino acid long region of the protein may also have up to 0.5%, 1%, 2%, 5%, 10%, 15%, 20%, 30%, 40%, 50%, 65%, 75%, or more amino acids replaced with conservative substitutions. Preferably the region will have fewer than 30%, 20%, 10% or even less conservative substitutions. The "percent amino acid sequence identity" calculation in such cases will be higher than the actual percent sequence identity when conservative amino acid substitutions have been made.

[44] "Percent nucleic acid sequence identity" with respect to the phage associated lytic enzyme sequences identified herein is defined as the percentage of nucleotides in a candidate sequence that are identical with the nucleotides in the phage associated lytic enzyme sequence, after aligning the sequences and introducing gaps, if necessary, to achieve the maximum percent sequence identity. Alignment for purposes of determining percent nucleic acid sequence identity may be achieved in various ways that are within the scope of those skilled in the art, including but not limited to the use of publicly available computer software. Those skilled in the art may determine appropriate parameters for measuring alignment, including any algorithms needed to achieve maximal alignment over the full length of the sequences being compared.

[45] "Polypeptide" refers to a molecule comprised of amino acids which correspond to those encoded by a polynucleotide sequence which is naturally occurring. The polypeptide may include conservative substitutions wherein the naturally occurring amino acid is replaced by one having similar properties, where such conservative substitutions do not alter the function of the polypeptide (see, for example, Lewin "Genes V" Oxford University Press Chapter 1, pp. 9-13 1994).

[46] A "chimeric protein" or "fusion protein" comprises all or (preferably a biologically active) part of a polypeptide of the disclosure operably linked to a heterologous polypeptide. Chimeric proteins or peptides are produced, for example, by combining two or more proteins having two or more active sites. Chimeric protein and peptides may act independently on the same or different molecules, and hence have a potential to treat two or more different bacterial infections at the same time. Chimeric proteins and peptides also are used to treat a bacterial infection by cleaving the cell wall in more than one location.

[47] The term "operably linked" means that the polypeptide of the disclosure and the heterologous polypeptide are fused in-frame. The heterologous polypeptide may be fused to the N-terminus or C-terminus of the polypeptide of the disclosure. Chimeric proteins are produced enzymatically by chemical synthesis, or by recombinant DNA technology. A number of chimeric lytic enzymes have been produced and studied. Gene E-L, a chimeric lysis constructed from bacteriophages phi X174 and MS2 lysis proteins E and L, respectively, was subjected to internal deletions to create a series of

new E-L clones with altered lysis or killing properties. The lytic activities of the parental genes E, L, E-L, and the internal truncated forms of E-L were investigated in this study to characterize the different lysis mechanism, based on differences in the architecture of the different membranes spanning domains. Electron microscopy and release of marker enzymes for the cytoplasmic and periplasmic spaces revealed that two different lysis mechanisms may be distinguished depending on penetration of the proteins of either the inner membrane or the inner and outer membranes of the *E. coli*. FEMS Microbiol. Lett. 1998 Jul 1, 164(1); 159-67 (incorporated herein by reference).

[48] Isolated bacteriophages γ and W may be used in the study of the relationship between the bacteriophages and their host cells (e.g., *B. anthracis*, such as *B. anthracis* species ITI 378). Isolated bacteriophages γ and W may also be used as a vector to deliver nucleic acids to a host cell; that is, the bacteriophage may be modified to deliver nucleic acids comprising a gene from an organism other than the bacteriophage (a "foreign" gene). For example, nucleic acids encoding a polypeptide (e.g., an enzyme or pharmaceutical peptide) may be inserted into the genome of bacteriophages γ and W, using standard techniques. The resultant modified bacteriophage may be then used to infect host cells, and the protein encoded by the foreign nucleic acids may then be produced.

[49] Phage, or bacterial viruses, are major mediators of bacterial genetic diversity. They persist in bacterial populations by stably integrating into the host genome (lysogenic growth as a prophage form) and/or by freely replicating within a host (lytic growth). During such passage the phage genome may acquire, maintain, and transmit "foreign" DNA (obtained from other phage or the bacterial host) which serves to enhance fitness of the host. This foreign DNA may promote bacterial exploitation of animal tissues (resulting from exotoxins, colonization factors, serum resistance proteins, etc.), and it is likely to promote survival in other niches as well. Despite the increasingly well described role for phage in pathogen evolution, their place in the pathogenesis of *B. anthracis* is unclear. Since the *B. anthracis* pool is so genetically uniform, it is unlikely that phage drive the emergence of distinctly pathogenic strains, as is the case for other Gram-positive pathogens like *Streptococcus pyogenes* and

Staphylococcus aureus. The role may rather be related to interactions (or a relationship) between *B. anthracis* and transition state *B. cereus*. Such possibility is based on studies from the 1940's and 50's showing that a lysogenic phage from the soil, called W, and an obligately lytic derivative thereof, called γ , infect both *B. anthracis* and the rare transition state *B. cereus* strains and thus may transmit information between the two. More recent studies suggest that several distinct naturally occurring and laboratory-induced *B. anthracis* phage may also infect certain *B. cereus* strains, which may have represented transition state isolates.

[50] Without being limited by theory, it is believed that *B. anthracis* is a genetically monomorphic variant of the otherwise highly polymorphic *B. cereus* lineage, which also includes *B. cereus* and *B. thuringiensis*. *B. anthracis* isolates recovered from diverse geographical locations or from present and past outbreaks are genetically distinguishable largely by molecular typing schemes that discriminate distinct and stable allelic states based on variations of tandem nucleotide-repeat elements in a few hypervariable loci. Several alternate analyses of genetic polymorphisms (multilocus enzyme electrophoretic studies, for example) show a very close phylogenetic relationship between *B. anthracis* and a group of rare *B. cereus* "transition state" strains, possessing both *B. anthracis*- and *B. cereus*-like qualities and that may be more readily recoverable from *B. anthracis* outbreak sites than is bona fide *B. anthracis*. The significance of this relationship to the ecology of anthrax is unclear. Currently, little is known regarding the fate of *B. anthracis* in the environment after host death, although it is held to involve stagenancy in the form of an absolutely dormant spore. Here, we report the identification and characterization of an environmental bacteriophage infecting both *B. anthracis* and a transition state *B. cereus* strain, and thus establishing a means for genetic exchange between the two. Lysogeny of either organism exerts profound phenotypic changes and with *B. anthracis*, involves the acquisition of *B. cereus*-like features.

[51] One embodiment of the invention relates to isolated γ or W bacteriophage. "Isolated" γ or W bacteriophage refers to bacteriophage that has been separated, partially or totally, from its native environment (e.g., separated from *B. anthracis* host

cells) ("native bacteriophage"), and also refers to bacteriophage that has been chemically synthesized or recombinantly produced ("recombinant bacteriophage"). A bacteriophage that has been "recombinantly produced" refers to a bacteriophage that has been manufactured using recombinant DNA technology, such as by inserting the bacteriophage genome into an appropriate host cell (e.g., by introducing the genome
5 itself into a host cell, or by incorporating the genome into a vector, which is then introduced into the host cell).

Isolation and Preparation of Bacteriophages

[52] Bacteriophages γ and W may be produced by inoculating appropriate host
10 cells with the bacteriophage. Representative host cells in which the bacteriophage may replicate include *B. anthracis*. The host cells may be cultured in a suitable medium (e.g., medium 162 for *Thermus* as described by Degryse et al., Arch. Microbiol. 117:189-196 (1978), with 1/10 buffer and with 1% NaCl). In addition, the host cells may be cultured under conditions suitable for replication of the bacteriophage. For example,
15 in a preferred embodiment, the host cells may be cultured at a temperature of at least approximately 50°C. In a more preferred embodiment, the host cells may be cultured at a temperature between about 50° C. and about 80°C. The bacteriophage may also be stored in a cell lysate at about 4°C.

NUCLEIC ACID SEQUENCES

20 [53] Another embodiment of the invention relates to isolated nucleic acid sequences obtainable from the genome of bacteriophages γ and W.

[54] The nucleic acid molecules of the invention may be "isolated;" as used herein, an "isolated" nucleic acid molecule or nucleotide sequence is intended to mean a nucleic acid molecule or nucleotide sequence which is not flanked by nucleotide
25 sequences which normally (in nature) flank the gene or nucleotide sequence (as in genomic sequences) and/or has been completely or partially purified from other transcribed sequences (e.g., as in an RNA library). For example, an isolated nucleic acid of the invention may be substantially isolated with respect to the complex cellular milieu in which it naturally occurs. In some instances, the isolated material will form
30 part of a composition (for example, a crude extract containing other substances), buffer

system or reagent mix. In other circumstance, the material may be purified to essential homogeneity, for example as determined by PAGE or column chromatography such as HPLC. Thus, an isolated nucleic acid molecule or nucleotide sequence may include a nucleic acid molecule or nucleotide sequence which is synthesized chemically or by recombinant means. Therefore, recombinant DNA contained in a vector may be included in the definition of "isolated" as used herein. Also, isolated nucleotide sequences include recombinant DNA molecules in heterologous organisms, as well as partially or substantially purified DNA molecules in solution. In vivo and in vitro RNA transcripts of the DNA molecules of the present invention may be also encompassed by "isolated" nucleotide sequences.

[55] The present invention also relates to nucleotide sequences which may be not necessarily found in nature but that encode the polypeptides described below. Thus, DNA molecules which comprise a sequence which is different from the naturally-occurring nucleotide sequence but which, due to the degeneracy of the genetic code, encode the polypeptides described herein, such as SEQ ID NO:3 – SEQ ID NO:109, are also provided. Embodiments of the invention also encompass variations of the nucleotide sequences of the invention, such as those encoding active fragments or active derivatives of the polypeptides as described below. Such variations may be naturally-occurring, or non-naturally-occurring, such as those induced by various mutagens and mutagenic processes. Intended variations include, but are not limited to, addition, deletion and substitution of one or more nucleotides which may result in conservative or non-conservative amino acid changes, including additions and deletions. Preferably, the nucleotide or amino acid variations are silent or conserved; that is, they do not alter the characteristics or activity of the encoded polypeptide.

[56] The invention also relates to fragments of the isolated nucleic acid molecules described herein. The term "fragment" encompasses a portion of a nucleotide sequence described that is from at least about 25 contiguous nucleotides to at least about 50 contiguous nucleotides or longer in length. These fragments may be useful as probes and also as primers. Particularly preferred primers and probes selectively hybridize to the nucleic acid molecule encoding the polypeptides described herein. For example,

fragments that encode polypeptides that retain activity, as described below, may be particularly useful.

[57] The invention also relates to nucleic acid molecules that hybridize under high stringency hybridization conditions, such as for selective hybridization, to a nucleotide sequence described herein (e.g., nucleic acid molecules which specifically hybridize to a nucleotide sequence encoding polypeptides described herein, and, optionally, have an activity of the polypeptide). Hybridization probes may be oligonucleotides that may bind in a base-specific manner to a complementary strand of nucleic acid. Suitable probes include polypeptide nucleic acids, as described in (Nielsen et al., Science 254, 1497-1500 (1991)).

[58] These nucleic acid molecules may be detected and/or isolated by specific hybridization (e.g., under high stringency conditions). "Stringency conditions" for hybridization is a term of art which refers to the incubation and wash conditions, e.g., conditions of temperature and buffer concentration, which permit hybridization of a particular nucleic acid to a second nucleic acid; the first nucleic acid may be perfectly (i.e., 100%) complementary to the second, or the first and second may share some degree of complementarity which is less than perfect (e.g., 60%, 75%, 85%, 95%). For example, certain high stringency conditions may be used which distinguish perfectly complementary nucleic acids from those of less complementarity.

[59] "High stringency conditions," "moderate stringency conditions" and "low stringency conditions" for nucleic acid hybridizations are explained on pages 2.10.1-2.10.16 and pages 6.3.1-6 in Current Protocols in Molecular Biology (Ausubel, F. M. et al., "Current Protocols in Molecular Biology," John Wiley & Sons, (1998)) the teachings of which are hereby incorporated by reference. The exact conditions which determine the stringency of hybridization depend not only on ionic strength (e.g., 0.2.times.SSC, 0.1.times.SSC), temperature (e.g., room temperature, 42°C., 68° C.) and the concentration of destabilizing agents such as formamide or denaturing agents such as SDS, but also on factors such as the length of the nucleic acid sequence, base composition, percent mismatch between hybridizing sequences and the frequency of

occurrence of subsets of that sequence within other non-identical sequences. Thus, high, moderate or low stringency conditions may be determined empirically.

[60] By varying hybridization conditions from a level of stringency at which no hybridization occurs to a level at which hybridization is first observed, conditions which will allow a given sequence to hybridize (e.g., selectively) with the most similar sequences in the sample may be determined.

[61] In one embodiment, PlyG may be used in the preparation of DNA, for example for hybridization studies. Using PlyG, DNA from *B. anthracis* can be rapidly and more gently extracted because of the specificity of PlyG for particular types of bacteria including *B. anthracis*. Accordingly, in this embodiment, less stringent hybridization conditions may be required to prepare DNA from bacteria that PlyG selectively acts upon than would otherwise be required in the absence of PlyG.

[62] Exemplary conditions are described in Krause, M. H. and S. A. Aaronson, Methods in Enzymology, 200:546-556 (1991). Also, in, Ausubel, et al., "Current Protocols in Molecular Biology," John Wiley & Sons, (1998), which describes the determination of washing conditions for moderate or low stringency conditions.

Washing is the step in which conditions are usually set so as to determine a minimum level of complementarity of the hybrids. Generally, starting from the lowest temperature at which only homologous hybridization occurs, each °C. by which the final wash temperature is reduced (holding SSC concentration constant) allows an increase by 1% in the maximum extent of mismatching among the sequences that hybridize. Generally, doubling the concentration of SSC results in an increase in $T_{sub.m}$ of about 17° C. Using these guidelines, the washing temperature may be determined empirically for high, moderate or low stringency, depending on the level of mismatch sought.

[63] For example, a low stringency wash may comprise washing in a solution containing 0.2.times.SSC/0.1% SDS for 10 min at room temperature; a moderate stringency wash may comprise washing in a prewarmed solution (42° C.) solution containing 0.2.times.SSC/0.1% SDS for 15 min at 42° C.; and a high stringency wash may comprise washing in prewarmed (68° C.) solution containing

0.1.times.SSC/0.1%SDS for 15 min at 68° C. Furthermore, washes may be performed repeatedly or sequentially to obtain a desired result as known in the art.

[64] Equivalent conditions may be determined by varying one or more of the parameters given as an example, as known in the art, while maintaining a similar degree of identity or similarity between the target nucleic acid molecule and the primer or probe used. Hybridizable nucleic acid molecules may be useful as probes and primers, e.g., for diagnostic applications.

[65] Examples of high stringency conditions may be selected from the group consisting of:

[66] (a) 0.015 M sodium chloride/0.0015 M sodium citrate/0.1% sodium dodecyl sulfate at 50°C;

[67] (b) 50% (v/v) formamide with 0.1% bovine serum albumin/0.1% Ficoll/0.1% polyvinylpyrrolidone/50mM sodium phosphate buffer at pH 6.5 with 750 mM sodium chloride, 75 mM sodium citrate at 42°C; and

[68] (c) 50% formamide, 5 x SSC (0.75 M sodium chloride, 0.075 M sodium citrate), 50 mM sodium phosphate (pH 6.8), 0.1% sodium pyrophosphate, 5 x Denhardt's solution, sonicated salmon sperm DNA (50 µg/ml), 0.1% sodium dodecyl sulphate, and 10% dextran sulfate at 42°C, with washes at 42°C in 0.2 x SSC (0.75 M sodium chloride, 0.075 M sodium citrate) and 50% formamide at 55°C, followed by a high-stringency wash consisting of 0.1 x SSC (0.75 M sodium chloride, 0.075 N sodium citrate) containing EDTA at 55°C.

[69] Such hybridizable nucleotide sequences may be useful as probes and primers for diagnostic applications. As used herein, the term "primer" refers to a single-stranded oligonucleotide which acts as a point of initiation of template-directed DNA synthesis under appropriate conditions (e.g., in the presence of four different nucleoside triphosphates and an agent for polymerization, such as, DNA or RNA polymerase or reverse transcriptase) in an appropriate buffer and at a suitable temperature. The appropriate length of a primer depends on the intended use of the primer, but typically ranges from 15 to 30 nucleotides. Short primer molecules generally require cooler temperatures to form sufficiently stable hybrid complexes with the template. A primer

need not reflect the exact sequence of the template, but must be sufficiently complementary to hybridize with a template. The term "primer site" refers to the area of the target DNA to which a primer hybridizes. The term "primer pair" refers to a set of primers including a 5' (upstream) primer that hybridizes with the 5' end of the DNA sequence to be amplified and a 3' (downstream) primer that hybridizes with the complement of the 3' end of the sequence to be amplified.

[70] As described herein, the genome of bacteriophages γ and W have been sequenced. The polynucleotide sequence of bacteriophage γ is set forth in **FIG. 1A** (SEQ ID NO:1), and corresponding polypeptide sequences for open reading frames of SEQ ID NO:1 are set forth in **FIG. 1B**. There are approximately 53 open reading frames (ORFs) in the polynucleotide sequence, as set forth in **Table 1**. The polynucleotide sequence of bacteriophage W is set forth in **FIG. 2A** (SEQ ID NO:2), and corresponding polypeptide sequences for open reading frames of SEQ ID NO:2 are set forth in **FIG. 2B**. There are approximately 54 open reading frames (ORFs) in the polynucleotide sequence of bacteriophage W, as set forth in **Table 2**. **Table 1** and **Table 2** relate to the locus of each ORF; the number of nucleotides in the ORF; the structure and function of various putative proteins encoded therein; the protein identified by a BLAST search as being the closest match to certain putative proteins; and other information relating to the ORFs.

[71] The invention thus relates to isolated nucleic acid sequence of the genome ("isolated genomic DNA") of the bacteriophages γ and W. The invention also relates to isolated nucleic acid sequence of the genome of bacteriophages γ and W. The invention additionally relates to isolated nucleic acid molecules comprising the nucleotide sequences of each of the ORFs described above or fragments thereof, as well as nucleic acid molecules comprising nucleotide sequences of more than one of the ORFs described above or fragments of more than one of the ORFs. The nucleic acid molecules of the invention may be DNA, or may also be RNA, for example, mRNA. DNA molecules may be double-stranded or single-stranded; single stranded RNA or DNA may be either the coding, or sense, strand or the non-coding, or antisense, strand. Preferably, the nucleic acid molecule comprises at least about 100 nucleotides, or at

least one ORF, or more preferably at least about 150 nucleotides, and even more preferably at least about 200 nucleotides. The nucleotide sequence may be only that which encodes at least a fragment of the amino acid sequence of a polypeptide; alternatively, the nucleotide sequence may include at least a fragment of a coding
5 sequence along with additional non-coding sequences such as non-coding 3' and 5' sequences (including regulatory sequences, for example). Certain preferred nucleotide sequences of the invention may consist essentially of one of the ORFs and its flanking sequences. For example, in certain preferred embodiments, the nucleotide sequence comprises one of the following ORFs: ORF 14 of the g-phage (Gp14), ORF 14 of the
10 W-phage (Wp14), and ORF 38 of the W-phage (Wp38).

Bacteriophage Gamma (γ)

[72] Analysis of the γ phage host range in **Table 1** demonstrated its specificity for *B. anthracis* and RSVF1. By electron microscopy (**FIG. 3A**), γ is morphologically similar to members of the *Siphoviridae* family of tailed phages (double-stranded DNA
15 viruses of the order *Caudovirales*) consisting of a DNA-filled isometric, icosahedral head (90 nm in diameter) and a long non-contractile tail (260 nm in length) connected distally to a small plate and a fibrous tail extension (75 nm in length). Phage particles adhered to cellular debris via the tips of the tail fibers (**FIG. 3B**).

[73] A Fos resistance gene (ORF 14, or “Gp41”) is found in γ and appears to be
20 derived from a similar sequence in Ba prophage ϕ 4537. This is based on 99% identity at the DNA level between *gp39*, *pg40* and *gp41* and sequences in a Ba prophage. The DNA surrounding this region of homology is quite divergent, suggesting the acquisition of the island by γ through recombination with the ϕ 4537 prophage. Since there is no obvious homology in W to have supported this insertion, it has likely arisen via a
25 illegitimate mechanism.

[74] Gp41 encodes a fosfomycin resistance protein, or a glutathione transferase. Analysis of the Ba genome (**FIG. 4A**) shows ~35 such proteins, while other *Bacillus* spp. and *Clostridium* have 10-15 each (**FIG. 4B**). Only in the Ba genome is a copy prophage encoded and therefore mobile.

[75] We have cloned the Gp41 locus into an IPTG-inducible *Bacillus* protein expression vector (pDG148) and established a system for stably transforming RSVF1. Introduction of the pDG148::pg41 clone into RSVF1 has resulted in a 4-log increase in resistance to the antibiotic fosfomycin (FIG. 4C). The MIC for fosfomycin was 62.5 $\mu\text{g ml}^{-1}$ for RSVF1 and RSVF1/pDG148 and 500 $\mu\text{g ml}^{-1}$ for RSVF1/pDG148::gp41.

Table 1. ORF's of Gamma (γ) Bacteriophage of *B. anthracis*

| ORF | Frame | Position | Size | Matches (E value)* | Structure† | Function‡ |
|-----|-------|-------------|-----------------|---|--|------------------------------------|
| 1 | 3 | 54-539 | 18.5 (161) | Orf21 ϕ 105 <i>B. subtilis</i> (5e-25), Phage terminase, small subunit (1e-6) | c-c domain | DNA packaging |
| 2 | 2 | 536-2233 | 65.1 (565) | Orf22 ϕ 105 <i>B. subtilis</i> (1e-151), Phage terminase, large subunit (2e-131) | | DNA packaging |
| 3 | 2 | 2249-3547 | 48.8 (432) | Gp3 ϕ 3626 <i>C. perfringens</i> (e-112) Phage portal protein (9e-53) | | Portal protein |
| 4 | 3 | 3510-4130 | 23.7 (206) | Gp5 ϕ 3626 <i>C. perfringens</i> (2e-49) <i>Caudovirales</i> prohead protease (9e-29) | c-c domain | Head maturation protease |
| 5 | 2 | 4169-5347 | 44.2 (392) | Orf27 ϕ 105 <i>B. subtilis</i> (4e-95) Phage capsid family (7e-72) | c-c domains | Major head protein |
| 6 | 1 | 5365-5655 | 11.0 (96) | Gp7 ϕ 3626 <i>C. perfringens</i> (2e-3) Phage QLRG family (1e-7) | | |
| 7 | 3 | 5652-5975 | 12.1 (107) | BA_4559 <i>B. anthracis</i> (6e-5) Bacteriophage head-tail adaptor (4e-9) | Pyrophosphatase domain | Putative head-tail adaptor |
| 8 | 1 | 5968-6408 | 16.2 (146) | BA_4558 <i>B. anthracis</i> (2e-16) CRPp0301 (2e-5) | | Uncharacterized protein |
| 9 | 3 | 6405-6764 | 13.9 (119) | BA_4557 <i>B. anthracis</i> (4e-15) CRPp0346 (5e-8) | | Uncharacterized protein |
| 10 | 3 | 6765-7373 | 22.9 (202) | Chte_p_1640 <i>C. thermocellum</i> (9e-29) CRPp0161 (6e-11) | c-c domain | Major tail protein |
| 11 | 1 | 7423-7740 | 11.8 (105) | BA_4555 <i>B. anthracis</i> (2e-3) | | |
| 12 | 3 | 7770-7946 | 7.0 (58) | | | |
| 13 | 1 | 7963-11814 | 139.4 (1283) | BA_4552-BA_4554 <i>B. anthracis</i> (>6e-25), CRPp0381 (4e-40) | c-c domains | Tail protein |
| 14 | 3 | 11829-13319 | 56.8 (496) | BA_4550 <i>B. anthracis</i> (e-153), CRPp0325 (2e-4) | c-c domain Pyridoxal-phosphate binding domain | Tail component |
| 15 | 2 | 13316-17311 | 149.8 (1331) | BA_4578-BA_4579 <i>B. anthracis</i> (>5e-20), CRPp0329 (2e-36) | c-c domains | Similar to myosin heavy chain |
| 16 | 1 | 17350-17775 | 15.0 (141) | BA_4545 <i>B. anthracis</i> (9e-57), Phage-related holin (3e-28) | 3 TM domains | Holin, host lysis |
| 17 | 3 | 17775-18476 | 26.3 (233) | BA_4545 <i>B. anthracis</i> (1e-112) Cell wall amidase (2e-43) | | Lysin, host lysis |
| 18 | -1 | 19031-18534 | 18.0 (165) | | c-c domain, 1 TM domain | May be a lipoprotein |
| 19 | -3 | 19230-19018 | 8.3 (70) | BA_4541 <i>B. anthracis</i> (4e-13) Helix-turn-helix XRE-family (1e-4) | HTH domain only | |
| 20 | 1 | 19414-19722 | 12.3 (102) | BA_4540 <i>B. anthracis</i> (2e-40) | | |
| 21 | 3 | 19719-19901 | 6.7 (60) | BA_4539 <i>B. anthracis</i> (3e-12) | 2 TM domains | |
| 22 | 3 | 19911-21200 | 49.3 (414) | BA_4538 <i>B. anthracis</i> (e-168) FtsK/SpoIIIE family: C- term. (1e-15) | c-c domain, P-loop (ATP/ GTP binding) | DNA translocation? Integration? |
| 23 | 1 | 21178-21759 | 25.2 (175) | BC1920 <i>B. cereus</i> (2e-61) | c-c domain | |
| 24 | -3 | 22029-21793 | 8.6 (78) | BC1914 <i>B. cereus</i> (5e-18) | | |
| 25 | 2 | 21863-22090 | 8.4 (75) | | 2 TM domains | |
| 26 | 1 | 22297-23160 | 33.3 (287) | BC4930 <i>B. cereus</i> (6e-11) | c-c domain | lysogeny? |
| 27 | 1 | 23236-24681 | 56.4 | Chte1631 <i>C. thermocellum</i> (2e-30) | c-c domains | Integrase |

| ORF | Frame | Position | Size | Matches (E value)* | Structure† | Function‡ |
|-----|-------|-------------|---------------|--|--|---|
| | | | (481) | PinR, Site-specific recombinases (4e-20) | | |
| 28 | -1 | 24812-24684 | 4.8 (39) | Helix-turn-helix XRE-family (0.01) | HTH domain fragment | Fragment of CI-like repressor? |
| 29 | 3 | 24972-25199 | 8.8 (75) | BC2559 <i>B. cereus</i> (7e-5) | HTH domain | Cro-like DNA binding role? |
| 30 | 3 | 25212-25397 | 7.2 (61) | BA_4542 <i>B. anthracis</i> (7e-5) | | |
| 31 | 1 | 25642-26457 | 31.0 (271) | Orf6 <i>L. lactis</i> ϕ BIL285 (2e-12), CRPp0355 (6e-17) | c-c domain | Anti-repressor |
| 32 | 1 | 26524-27177 | 25.7 (217) | Orf16 <i>L. lactis</i> ϕ BIL312 (4e-12) | | |
| 33 | 3 | 27306-28253 | 37.1 (315) | Orf11 <i>L. lactis</i> ϕ rlt (1e-18) | c-c domain | Phage replication; Origin of replication |
| 34 | 3 | 28269-29180 | 34.9 (303) | DnaA phage analogs DnaC DNA replication protein (3e-10) | AT-rich repeats c-c domain, P-loop (ATP-GTP binding) | Phage replication |
| 35 | 3 | 29199-29432 | 9.2 (77) | Ntp <i>Lactobacillus</i> ϕ g1e (6e-29) | | |
| 36 | 1 | 29425-30171 | 28.1 (248) | BA_4585 <i>B. anthracis</i> (6e-41) | | Transcriptional effects |
| 37 | 3 | 30168-30644 | 19.0 (158) | FliA family of sigma factors (1e-20) | | |
| 38 | 2 | 30704-31246 | 21.1 (180) | BA_5241 <i>B. anthracis</i> (2e-20) | | |
| 39 | 1 | 31270-31500 | 8.8 (76) | BA_4582 <i>B. anthracis</i> (1e-20) | 2 TM domains (signal sequence) | Membrane protein |
| 40 | 2 | 31607-32077 | 18.1 (156) | BA_4581 <i>B. anthracis</i> (2e-47) | | |
| 41 | -1 | 32124-32513 | 15.5 (129) | BA_4580 <i>B. anthracis</i> (2e-58) | | Fosfomycin resistance |
| 42 | 3 | 32994-33164 | 6.5 (56) | Glyoxalase resistance protein (1e-7) | | |
| 43 | 2 | 33353-33658 | 11.9 (101) | | c-c domain | |
| 44 | 3 | 33651-33890 | 9.3 (79) | | | |
| 45 | 1 | 34327-34734 | 16.0 (135) | BC3700 <i>B. cereus</i> (1e-39) | c-c domains | |
| 46 | 3 | 34854-35078 | 8.5 (74) | | c-c domains | |
| 47 | 3 | 35085-35306 | 8.2 (73) | | | 30% identity to C-term. half of hamster IL-6 |
| 48 | 1 | 35311-35715 | 15.6 (134) | | | |
| 49 | 3 | 35820-36011 | 7.2 (63) | | | |
| 50 | 1 | 36031-36285 | 10.2 (84) | | c-c domains | |
| 51 | 1 | 36484-36675 | 7.3 (63) | | | |
| 52 | 2 | 36656-36943 | 10.6 (95) | BA_4569 <i>B. anthracis</i> (5e-4) | c-c domains | |
| 53 | 1 | 36943-37326 | 15.5 (128) | Gp50 ϕ 3626 <i>C. perfringens</i> (6e-13) McrA restriction endonuclease (2e-5) | | endonuclease |

*No entry indicates no significant homologies based on a protein-protein BLAST search. First line indicates the protein name, organism of origin, and BLAST E value for most significant hit. Second line indicates, if detected, the pfam conserved domain and E value or the cluster of related viral proteins (CRP) designation and E value.

†Indicates a significant protein structure or motif detected by bioinformatics analysis. Abbreviations are used: c-c domain/s, indicating the significant likelihood of one or more coiled-coil domains; TM, for transmembrane domain; and HTH, for helix-turn-helix.

‡Indicates putative function based on homologies detected with proteins of known function.

Bacteriophage W

[76] We also isolated the parental lysogenic phage, W. As part of a study of resistance to fosfomycin in *B. cereus* strains tested, ATCC 11950 produced unusual ring-shaped colonies when plated in the presence of fosfomycin (FIG. 3C), but not in the absence (FIG. 3D). The central clearing zone was found to be enriched for intact phage W particles, thus suggesting that the fosfomycin may have induced the phage from older colony members, which constitute the central portion of a colony. Much like γ , phage W infected both *B. anthracis* and RSVF1, and not other *B. cereus* or *B. thuringiensis* strains. Phage W was also morphologically identical to γ , confirming their close genetic relationship.

Table 2: ORF's of W-Bacteriophage of *B. anthracis*.

| Wp | Frame | Position | Size | Matches (E value)* | Structure† | Function‡ |
|----|-------|-------------|-----------------|---|---|------------------------------------|
| 1 | 3 | 54-539 | 18.5 (161) | Orf21 ϕ 105 <i>B. subtilis</i> (5e-25), Phage terminase, small subunit (1e-6) | c-c domain | Terminase, small subunit |
| 2 | 2 | 536-2233 | 65.1 (565) | Orf22 ϕ 105 <i>B. subtilis</i> (1e-151), Phage terminase, large subunit (2e-131) | | Terminase |
| 3 | 2 | 2249-3547 | 48.8 (432) | Gp3 ϕ 3626 <i>C. perfringens</i> (e-112) Phage portal protein (9e-53) | | Portal protein |
| 4 | 3 | 3510-4130 | 23.7 (206) | Gp5 ϕ 3626 <i>C. perfringens</i> (2e-49) <i>Caudovirales</i> prohead protease (9e-29) | c-c domain | Head maturation protease |
| 5 | 2 | 4169-5347 | 44.2 (392) | Orf27 ϕ 105 <i>B. subtilis</i> (4e-95) Phage capsid family (7e-72) | c-c domains | Major head protein |
| 6 | 1 | 5365-5655 | 11.0 (96) | Gp7 ϕ 3626 <i>C. perfringens</i> (2e-3) Phage QLRG family (1e-7) | | |
| 7 | 3 | 5652-5975 | 12.1 (107) | BA_4559 <i>B. anthracis</i> (6e-5) Bacteriophage head-tail adaptor (4e-9) | Pyrophosphatase domain | Putative head-tail adaptor |
| 8 | 1 | 5968-6408 | 16.2 (146) | BA_4558 <i>B. anthracis</i> (2e-16) CRPp0301 (2e-5) | s | Uncharacterized protein |
| 9 | 3 | 6405-6764 | 13.9 (119) | BA_4557 <i>B. anthracis</i> (4e-15) CRPp0346 (5e-8) | | Uncharacterized protein |
| 10 | 3 | 6765-7373 | 22.9 (202) | Chte_p_1640 <i>C. thermocellum</i> (9e-29) CRPp0161 (6e-11) | c-c domain | Major tail protein |
| 11 | 1 | 7423-7740 | 11.8 (105) | BA_4555 <i>B. anthracis</i> (2e-3) | | |
| 12 | 3 | 7770-7946 | 7.0 (58) | | | |
| 13 | 1 | 7963-11814 | 139.4 (1283) | BA_4552-BA_4554 <i>B. anthracis</i> (>6e-25), CRPp0381 (4e-40) | c-c domains | Tail protein |
| 14 | 3 | 11829-13319 | 56.8 (496) | BA_4550 <i>B. anthracis</i> (e-153), CRPp0325 (2e-4) | c-c domain, Pyridoxal-phosphate binding domain | Putative tail component protein |
| 15 | 2 | 13316-17311 | 149.8 (1331) | BA_4578-BA_4579 <i>B. anthracis</i> (>5e-20), CRPp0329 (2e-36) | c-c domains | Similar to myosin heavy chain |
| 16 | 1 | 17350-17775 | 15.0 (141) | BA_4545 <i>B. anthracis</i> (9e-57), Phage-related holin (3e-28) | 3 TM domains | Holin |
| 17 | 3 | 17775-18476 | 26.3 (233) | BA_4545 <i>B. anthracis</i> (1e-112) Cell wall amidase (2e-43) | | Lysin |
| 18 | -1 | 19031-18534 | 18.0 (165) | | c-c domain, 1 TM domain | May be a lipoprotein |
| 19 | -3 | 19230-19018 | 8.3 (70) | BA_4541 <i>B. anthracis</i> (4e-13) Helix-turn-helix XRE-family (1e-4) | HTH domain only | |
| 20 | 1 | 19414-19722 | 12.3 (102) | BA_4540 <i>B. anthracis</i> (2e-40) | | |
| 21 | 3 | 19719-19901 | 6.7 (60) | BA_4539 <i>B. anthracis</i> (3e-12) | 2 TM domains | |
| 22 | 3 | 19911-21200 | 49.3 (414) | BA_4538 <i>B. anthracis</i> (e-168) FtsK/SpoIIIE family: C-term. (1e-15) | c-c domain, P-loop (ATP/ GTP binding) | DNA translocation? Integration? |

| Wp | Frame | Position | Size | Matches (E value)* | Structure† | Function‡ |
|------|-------|-------------|---------------|---|---|--|
| 23 | 1 | 21178-21759 | 25.2 (175) | BC1920 <i>B. cereus</i> (2e-61) | c-c domain | |
| 24 | -3 | 22029-21793 | 8.6 (78) | BC1914 <i>B. cereus</i> (5e-18) | | |
| 25 | 2 | 21863-22090 | 8.4 (75) | | 2 TM domains | |
| 26 | 2 | 22325-23188 | 33.3 (287) | BC4930 <i>B. cereus</i> (6e-11) | c-c domain | Transcriptional effects? |
| 27 | 2 | 23264-24709 | 56.4 (481) | Cht1631 <i>C. thermocellum</i> (2e-30) PinR, Site-specific recombinases (4e-20) | c-c domains | Integrase |
| 28 | 2 | 24812-26146 | 51.2 (444) | Orf4 <i>B. thuringiensis</i> pAW63 plasmid (3e-6) | | Absent from γ |
| 28.1 | -3 | 26488-26844 | 13.6 (115) | BC2558 <i>B. cereus</i> (1e-11) Helix-turn-helix Cro and CI family (2e-7) | c-c domain | CI-like DNA binding role? Absent from γ |
| 29 | 1 | 27004-27231 | 8.8 (75) | BC2559 <i>B. cereus</i> (7e-5) Helix-turn-helix Cro and CI family (0.008) | HTH domain | Cro-like DNA binding role? |
| 30 | 1 | 27244-27429 | 7.2 (61) | BA_4542 <i>B. anthracis</i> (7e-5) | | |
| 31 | 2 | 27674-28489 | 31.0 (271) | Orf6 <i>L. lactis</i> ϕ bil285 (2e-12), CRPp0355 (6e-17) | c-c domain | Anti-repressor |
| 32 | 2 | 28556-29209 | 25.7 (217) | Orf16 <i>L. lactis</i> ϕ bil312 (4e-12) | | |
| 33 | 1 | 29338-30285 | 37.1 (315) | DnaA phage analogs Orf11 <i>L. lactis</i> ϕ rlt (1e-18) | c-c domain AT-rich repeats | Phage replication; Origin of replication |
| 34 | 1 | 30301-31212 | 34.9 (303) | DnaC DNA replication protein (3e-10) Ntp <i>Lactobacillus</i> ϕ g1e (6e-29) | c-c domain; P-loop (ATP-GTP binding) | Phage replication |
| 35 | 1 | 31231-31464 | 9.2 (77) | | | |
| 36 | 2 | 31457-32203 | 28.1 (248) | BA_4585 <i>B. anthracis</i> (6e-41) FliA family of sigma factors (1e-20) | | Transcriptional effects |
| 37 | 1 | 32200-32676 | 19.0 (158) | | | |
| 38 | 3 | 32736-33278 | 21.1 (180) | BA_5241 <i>B. anthracis</i> (2e-20) | | |
| 39 | 1 | 33514-34446 | 28.7 (310) | Bcol14-2 <i>B. thuringiensis</i> pTX14-2 plasmid (6e-83) | 4 collagen-like triple helix repeats | Spore surface antigen |
| 40 | 3 | 34440-34931 | 16.8 (163) | BC4769 <i>B. cereus</i> (2e-26) C.-term half of collagen triple helix repeat protein | 4 TM domains | |
| 41 | -2 | 35903-35379 | 21.2 (191) | CTC01899 <i>C. tetani</i> (2e-54) Mannose-6-phosphate isomerase (5e-19) | | Nutrient acquisition or a role in surface carbohydrate structure |
| 42 | 1 | 36490-36660 | 6.5 (56) | | | |
| 43 | 3 | 36849-37154 | 11.9 (101) | | c-c domain | |
| 44 | 1 | 37147-37386 | 9.3 (79) | | | |
| 45 | 2 | 37823-38230 | 16.0 (135) | BC3700 <i>B. cereus</i> (1e-39) | c-c domains | |
| 46 | 1 | 38350-38574 | 8.5 (74) | | c-c domains | |
| 47 | 1 | 38581-38802 | 8.2 (73) | | | 30% identity to C-term. half of hamster IL-6 |
| 48 | 2 | 38807-39211 | 15.6 (134) | | | |
| 49 | 1 | 39316-39507 | 7.2 (63) | | | |
| 50 | 2 | 39527-39781 | 10.2 (84) | | c-c domains | |
| 51 | 2 | 39980-40171 | 7.3 (63) | | | |
| 52 | 3 | 40152-40439 | 10.6 (95) | BA_4569 <i>B. anthracis</i> (5e-4) | c-c domains | |
| 53 | 2 | 40439-40822 | 15.5 (128) | Gp50 ϕ 3626 <i>C. perfringens</i> (6e-13) McrA restriction endonuclease (2e-5) | | endonuclease |

*No entry indicates no significant homologies based on a protein-protein BLAST search. First line indicates the protein name, organism of origin, and BLAST E value for most significant hit. Second line indicates, if detected, the pfam conserved domain and E value or the cluster of related viral proteins (CRP) designation and E value.

†Indicates a significant protein structure or motif detected by bioinformatics analysis. Abbreviations are used: c-c domain/s, indicating the significant likelihood of one or more coiled-coil domains; TM, for transmembrane domain; and HTH, for helix-turn-helix.
‡Indicates putative function based on homologies detected with proteins of known function.

5 POLYNUCLEOTIDE SEQUENCE COMPARISON

[77] Similar Features of γ and W Bacteriophage Sequences

[78] The genomic sequences of both γ and W were determined and shown by pairwise comparison to be 100% identical with exceptions at four loci (**Fig. 5A**). The G_C contents of γ and W were 35.1% and 35.3%, respectively, similar to that of the *B. anthracis* genome (36.4%). Complementary 9 bp 5'-single-stranded cohesive ends (cos sites) flanked both phage. The γ phage encoded 53 ORFs over 37,367 bp, while the parental W phage had 54 ORFs within its 40,864 bp genome.

[79] A common feature of the lambdoid genomes is a genetic mosaicism that results from rampant recombination and the horizontal transfer of functional gene modules (discrete transcriptional units containing one or more genes) among related phage genomes infecting, perhaps, a disparate range of bacterial organisms. As such, the genomes appear as a 'pasting' of modules from different sources, encoding part or all of each of the basic phage functions, including capsid building, host lysis, lysogeny, and replication. The architecture of the γ and W genomes is consistent with this model. The virion structural and host lysis proteins of γ and W (ORFs 1-17), are the most well conserved components, similar in both sequence and gene order to phage elements encoded by phages ϕ 3626 of *Clostridium perfringens*, ϕ 105 of *B. subtilis* or ϕ 4537 and ϕ 4241 prophages deduced from the *B. anthracis* genome (**FIG. 5B**). The lysogeny genes (ORFs 26-30) are divergent, showing homology for phage elements of *B. cereus*, *C. thermocellum*, *Lactococcus lactis* and a plasmid gene of *Bacillus spp.* The replication module (ORFs 31-34) is primarily similar to replication elements from phage of *L. lactis* and lactobacilli. In this manner, the functional genes of γ and W are indeed an assembled mosaic. A high proportion of genes (61 and 62% for the W and γ genomes, respectively) are similar to phage proteins from Gram⁺ spore forming bacteria. Twenty-one of these genes are similar to elements of *B. anthracis* ϕ 4537, and within this group, eight genes are found nowhere else. Alignment of the W phage and with the complete ϕ 4537 genome and the late genes of ϕ 4241 are presented (**FIG. 5C**) to illustrate the extent of this homology and the likelihood that W (and thus γ) arose

from a common precursor of these phage. This divergence was likely not recent owing to the notable difference between the W and ϕ 4537 genomes seen in **FIG. 5C**, and the presence of twelve largely unlinked γ and W loci are novel genes unrelated to known phage and host proteins. One feature of the γ and W genomes is the presence of 8 loci
5 between the Orf17 amidase and the lysogenic module (starting at Orf26), which are similar only to *B. anthracis* and *B. cereus* phage. Notably in *Streptococcal* phage, this position often encodes genes not for phage function, but for lysogenic conversion of the host. This region in γ and W notably encodes two host membrane proteins and a 1242 bp gene homologous to the 5' half of the bacterial host cell division protein FtsK. The
10 presence of an FtsK homolog in *B. anthracis* and transition strains may relate to the notable chain-like morphology of these organisms. Downstream of the replication module is another notable *B. anthracis* phage-specific host factor, Orf35, encoding a homolog of the sporulation sigma factor sigma F. Sigma F directs the RNA polymerase holoenzyme to a specific set of gene promoters within the developing spore of *Bacillus* spp. The presence of such a regulatory factor in W phage suggest that lysogeny may be
15 accompanied by alterations in host gene expression.

[80] Features of which differ between γ and W Bacteriophage Sequences

[81] Differences between γ and W, were observed with respect to the phage and to the host. Four changes have occurred in γ (compared to W) in the 50 years since its
20 isolation and use as a diagnostic phage for *B. anthracis*. Without being bound by theory, it is believed that two alterations in the lysogeny module relate to the conversion of γ from a lysogenic to a lytic phage. It is further believed that a set of alterations with a single tail fiber gene explains the reported alteration in host specificity (ability of γ to infect encapsulated *B. anthracis*) and defines the gene which
25 is essentially the basis for the widespread use of γ as a diagnostic tool. The last alternation is believed to be particularly significant, and involves the replacement of a three gene island in W with an alternate three gene island in γ .

[82] Changes in the lysogeny module

[83] Changes in the gamma lysogeny module (ORFs 26-32) may explain the
30 derivation of gamma from W. The lysogeny region is a known hotspot for

recombination in several phage, including W. The decision between lytic and lysogenic growth is often influenced by a genetic switch region encoding two divergently transcribed small DNA binding repressor proteins, which represent functional homologs of the well studied CI and Cro proteins of L phage. In phage W, the CI and Cro-like functions are likely encoded by wp28.1 and wp29, with Wp28.1 (CI-like) required for repressing the lytic proliferation genes and promoting lysogeny and Wp29 (Cro-like) required for repressing expression of the lysogeny module and promoting lytic growth. In the gamma phage, the lytic-only variant of W, both Wp28.1 and the adjacent gene Wp28 have been lost as part of a 2003 bp deletion that fused the 5' third of Wp28.1 to a short peptide sequence between Wp27 and Wp28, creating Gp28, a presumed gene fragment encoding only a partial helix-turn-helix DNA binding motif. In addition to this, there is a 28 bp deletion in an intergenic region between ORFs25 and 26, which is immediately adjacent to the phage attachment (att) site, which is required for insertion of the phage into the host genome during the establishment of the lysogenic state. Without being limited to theory, it is believed that the gamma bacteriophage has developed as a lytic variant through two separate deletion events at sites required for lysogenic functions.

[84] *Changes in the Orf14 tail fiber gene*

[85] We sought to identify γ encoded genes that specify the interaction with the surface of *B. anthracis*. Elements which are the basis of diagnostic tools and also key to the phage infection cycle. Two likely candidates observed in genome — PlyG (lysine known to bind Ba, however it has same sequence in both γ and W) and Orf14 (putative tail fiber, which has undergone major change in gamma compared to W). We investigated the ability of each to bind Ba and RSVF1 using GFP protein fusions.

[86] At least 69 missense mutations have occurred in γ ORF14 (referred to as Gp14) since its isolation from W 50 years ago. The resultant proteins differ by 24 amino acid residues (92% identity), likely affecting structural changes in the binding domain need for improved infection of a *B. anthracis* host. The gene appears to have arisen specifically in the Ba phage through insertion of a novel binding module into a tail fiber found in many bacillus phage.

[87] Three gene island in W phage polynucleotide sequence

[88] The W phage as a 2824 bp three gene island (ORFs 39-41) encoding a putative spore surface antigen, a transmembrane domain that may be expressed with the surface antigen as part of a translational frameshift mechanism, and an enzyme (often associated with pathogenicity islands) which is a mannose-6-phosphate isomerase. The spore antigen appears to be similar, but not identical to, fibrous appendages that are found on the surface of spores, are the dominant surface antigen of spores, and are likely involved in the initial infection process of *Bacillus anthracis*. The mannose-6-phosphate isomerase is often considered a horizontally transferred virulence associated gene involved in generating alterations in surface carbohydrate structure in Gram⁻ bacteria. This three gene island appears to encode proteins not required directly for the phage lifecycle, but are rather of use to the host (lysogenic conversion genes). The gamma phage has lost this island probably due to recombination with a three gene segment in *B. anthracis* ϕ 4567. This 1360 bp segment (replacing the 2824 bp W island) is 99% identical to sequence in γ . This island encodes two proteins found only in Ba phage, and also a Fosfomycin resistance gene. The Fos gene (Gp41) is similar to this family of proteins, which act as glutathione S transferases. Similar genes are found in most bacteria, however, only in Ba is it phage encoded. Most soil bacteria examined (*Clostridium spp.*, *Bacillus subtilis*, *Bacillus cereus*, have about 10-15 glutathione S transferase-like genes, while *B. anthracis* has almost 40.

[89] **Other Polynucleotide Sequences**

[90] The invention also relates to nucleotide sequences which have a substantial identity with the nucleotide sequences described herein; particularly preferred are nucleotide sequences which have at least about 10%, preferably at least about 20%, more preferably at least about 30%, more preferably at least about 40%, even more preferably at least about 50%, yet more preferably at least about 70%, still more preferably at least about 80%, and even more preferably at least about 90% identity, or 95% identity or more, with nucleotide sequences described herein. Particularly preferred in this instance are nucleotide sequences encoding polypeptides having an activity of a polypeptide described herein. For example, in one embodiment, the nucleotide sequence encodes a DNA polymerase, 3'-5' exonuclease, 5'-3' exonuclease

(RNase H), DNA helicase, or RNA ligase, as described below. In a preferred embodiment, the nucleotide encodes a DNA polymerase lacking exonuclease domains, or a 3'-5' exonuclease lacking DNA polymerase domain, as described below.

[91] To determine the percent identity of two nucleotide sequences, the sequences are aligned for optimal comparison purposes (e.g., gaps may be introduced in the sequence of a first nucleotide sequence). The nucleotides at corresponding nucleotide positions are then compared. When a position in the first sequence is occupied by the same nucleotide as the corresponding position in the second sequence, then the molecules are identical at that position. The percent identity between the two sequences is a function of the number of identical positions shared by the sequences (i.e., % identity=# of identical positions/total # of positions.times.100).

[92] The determination of percent identity between two sequences may be accomplished using a mathematical algorithm. A preferred, non-limiting example of a mathematical algorithm utilized for the comparison of two sequences is the algorithm of Karlin et al., Proc. Natl. Acad. Sci. USA, 90:5873-5877 (1993). Such an algorithm is incorporated into the NBLAST program which may be used to identify sequences having the desired identity to nucleotide sequences of the invention. To obtain gapped alignments for comparison purposes, Gapped BLAST may be utilized as described in Altschul et al., Nucleic Acids Res, 25:3389-3402 (1997). When utilizing BLAST and Gapped BLAST programs, the default parameters of the respective programs (e.g., NBLAST) may be used. See the programs provided by National Center for Biotechnology Information, National Library of Medicine, National Institutes of Health. In one embodiment, parameters for sequence comparison may be set at W=12. Parameters may also be varied (e.g., W=5 or W=20). The value "W" determines how many continuous nucleotides must be identical for the program to identify two sequences as containing regions of identity.

[93] One skilled in the art will recognize that the DNA mutagenesis techniques described here may produce a wide variety of DNA molecules that code for a bacteriophage lysin specific for *Bacillus anthracis* yet that maintain the essential characteristics of the lytic protein. Newly derived proteins may also be selected in order to obtain variations on the characteristic of the lytic protein, as will be more fully

described below. Such derivatives include those with variations in amino acid sequence including minor deletions, additions and substitutions.

[94] While the site for introducing an amino acid sequence variation is predetermined, the mutation per se does not need to be predetermined. For example, in order to optimize the performance of a mutation at a given site, random mutagenesis may be conducted at the target codon or region and the expressed protein variants screened for the optimal combination of desired activity. Techniques for making substitution mutations at predetermined sites in DNA having a known sequence as described above are well known.

[95] Amino acid substitutions are typically of single residues; insertions usually will be on the order of about from 1 to 10 amino acid residues; and deletions will range about from 1 to 30 residues. Deletions or insertions may be in single form, but preferably are made in adjacent pairs, i.e., a deletion of 2 residues or insertion of 2 residues. Substitutions, deletions, insertions or any combination thereof may be combined to arrive at a final construct. Obviously, the mutations that are made in the DNA encoding the protein must not place the sequence out of reading frame and preferably will not create complementary regions that could produce secondary mRNA structure (EP 75,444A).

[96] Substitutional variants are those in which at least one residue in the amino acid sequence has been removed and a different residue inserted in its place. Such substitutions may be made in accordance with the following Table 3 when it is desired to finely modulate the characteristics of the protein. Table 3 shows amino acids which may be substituted for an original amino acid in a protein and which are regarded as conservative substitutions.

Table 3

| Original Residue | Conservative Substitutions |
|---------------------|-------------------------------|
| Ala | ser |
| Arg | lys |
| Asn | gln, his |
| Asp | glu |
| Cys | ser |
| Gln | asn |

| | | |
|----|-----|---------------|
| | Glu | asp |
| | Gly | pro |
| | His | asn; gln |
| | Ile | leu, val |
| 5 | Leu | ile; val |
| | Lys | arg; gln; glu |
| | Met | leu; ile |
| | Phe | met; leu; tyr |
| | Ser | thr |
| 10 | Thr | ser |
| | Trp | tyr |
| | Tyr | trp; phe |
| | Val | ile; leu |

15

[97] Substantial changes in function or immunological identity are made by selecting substitutions that are less conservative than in Table 3, i.e., selecting residues that differ more significantly in their effect on maintaining: (a) the structure of the polypeptide backbone in the area of the substitution, for example, as a sheet or helical
20 conformation; (b) the charge or hydrophobicity of the molecule at the target site; or (c) the bulk of the side chain. The substitutions which in general are expected to produce the greatest changes in protein properties will be those in which: (a) a hydrophilic residue, e.g., seryl or threonyl, is substituted for (or by) a hydrophobic residue, e.g., leucyl, isoleucyl, phenylalanyl, valyl or alanyl; (b) a cysteine or proline is substituted
25 for (or by) any other residue; (c) a residue having an electropositive side chain, e.g., lysyl, arginyl, or histadyl, is substituted for (or by) an electronegative residue, e.g., glutamyl or aspartyl; or (d) a residue having a bulky side chain, e.g., phenylalanine, is substituted for (or by) one not having a side chain, e.g., glycine.

[98] The effects of these amino acid substitutions or deletions or additions may be
30 assessed for derivatives of the lytic protein by analyzing the ability of the derivative proteins to complement the sensitivity to DNA cross-linking agents exhibited by phages in infected bacteria hosts. These assays may be performed by transfecting DNA molecules encoding the derivative proteins into the bacteria as described above.

[99] Having herein provided nucleotide sequences that code for lytic enzyme
35 genetically coded for by a bacteriophage specific for *Bacillus anthracis* and fragments of that enzyme, correspondingly provided are the complementary DNA strands of the

cDNA molecule and DNA molecules which hybridize under stringent conditions to the lytic enzyme cDNA molecule or its complementary strand. Such hybridizing molecules include DNA molecules differing only by minor sequence changes, including nucleotide substitutions, deletions and additions. Also contemplated by this disclosure are isolated oligonucleotides comprising at least a segment of the cDNA molecule or its complementary strand, such as oligonucleotides which may be employed as effective DNA hybridization probes or primers useful in the polymerase chain reaction. Hybridizing DNA molecules and variants on the lytic enzyme cDNA may readily be created by standard molecular biology techniques.

10 [100] The detection of specific DNA mutations may be achieved by methods such as hybridization using specific oligonucleotides (Wallace et al. (1986). Cold Spring Harbor Symp. Quant. Biol. 51:257-261), direct DNA sequencing (Church and Gilbert (1988). Proc. Natl. Acad. Sci. USA 81:1991-1995), the use of restriction enzymes (Flavell et al. (1978). Cell 15:25), discrimination on the basis of electrophoretic mobility in gels with denaturing reagent (Myers and Maniatis (1986). Cold Spring Harbor Symp. Quant. Biol. 51:275-284), RNase protection (Myers et al. (1985). Science 230:1242), chemical cleavage (Cotton et al. (1985). Proc. Natl. Acad. Sci. USA 85:4397-4401) (incorporated herein by reference), and the ligase-mediated detection procedure (Landegren et al., 1988).

20 **EXPRESSION VECTORS**

[101] The invention also relates to expression vectors containing a nucleic acid sequence encoding a polypeptide described herein (or an active derivative or fragment thereof), operably linked to at least one regulatory sequence. Many expression vectors are commercially available, and other suitable vectors may be readily prepared by the skilled artisan. "Operably linked" is intended to mean that the nucleotide sequence is linked to a regulatory sequence in a manner which allows expression of the nucleic acid sequence. Regulatory sequences are art-recognized and are selected to produce the polypeptide or active derivative or fragment thereof. The term "regulatory sequence" includes promoters, enhancers, and other expression control elements which are described in Goeddel, Gene Expression Technology: Methods in Enzymology 185, Academic Press, San Diego, Calif. (1990). For example, the native regulatory

sequences or regulatory sequences native to bacteriophages γ and W may be employed. It should be understood that the design of the expression vector may depend on such factors as the choice of the host cell to be transformed and/or the type of polypeptide desired to be expressed. For instance, the polypeptides of the present invention may be produced by ligating the cloned gene, or a portion thereof, into a vector suitable for expression in an appropriate host cell (see, for example, Broach, et al., *Experimental Manipulation of Gene Expression*, ed. M. Inouye (Academic Press, 1983) p. 83; *Molecular Cloning: A Laboratory Manual*, 2nd Ed., ed. Sambrook et al. (Cold Spring Harbor Laboratory Press, 1989) Chapters 16 and 17). Typically, expression constructs will contain one or more selectable markers, including, but not limited to, the gene that encodes dihydrofolate reductase and the genes that confer resistance to neomycin, tetracycline, ampicillin, chloramphenicol, kanamycin and streptomycin resistance. Thus, prokaryotic and eukaryotic host cells transformed by the described expression vectors are also provided by this invention. The host cells may be transformed by the described vectors by various methods (e.g., electroporation, transfection using calcium chloride, rubidium chloride, calcium phosphate, DEAE-dextran, or other substances; microprojectile bombardment; lipofection, infection where the vector is an infectious agent such as a retroviral genome, and other methods), depending on the type of cellular host. The nucleic acid molecules of the present invention may be produced, for example, by replication in such a host cell, as described above. Alternatively, the nucleic acid molecules may also be produced by chemical synthesis.

PROBES

[102] The isolated nucleic acid molecules and vectors of the invention are useful in the manufacture of the encoded polypeptide, as probes for isolating homologous sequences (e.g., from other bacteriophage species), as well as for detecting the presence of the bacteriophage in a culture of host cells.

[103] The nucleotide sequences of the nucleic acid molecules described herein (e.g., a nucleic acid molecule comprising any of the open reading frames shown in **Table 1** or **Table 2** may be amplified by methods known in the art. For example, this may be accomplished by e.g., PCR. See generally *PCR Technology: Principles and*

Applications for DNA Amplification (ed. H. A. Erlich, Freeman Press, NY, N.Y., 1992); PCR Protocols: A Guide to Methods and Applications (eds. Innis, et al., Academic Press, San Diego, Calif., 1990); Mattila et al., Nucleic Acids Res. 19, 4967 (1991); Eckert et al., PCR Methods and Applications 1, 17 (1991); PCR (eds. McPherson et al., IRL Press, Oxford); and U.S. Pat. No. 4,683,202.

5 [104] Other suitable amplification methods include the ligase chain reaction (LCR) (see Wu and Wallace, Genomics 4, 560 (1989), Landegren et al., Science 241, 1077 (1988), transcription amplification (Kwoh et al., Proc. Natl. Acad. Sci. USA 86, 1173 (1989)), and self-sustained sequence replication (Guatelli et al., Proc. Nat. Acad. Sci. 10 USA, 87, 1874 (1990)) and nucleic acid based sequence amplification (NASBA). The latter two amplification methods involve isothermal reactions based on isothermal transcription, which produce both single stranded RNA (ssRNA) and double stranded DNA (dsDNA) as the amplification products in a ratio of about 30 or 100 to 1, respectively.

15 [105] The amplified DNA may be radiolabelled and used as a probe for screening a library or other suitable vector to identify homologous nucleotide sequences. Corresponding clones may be isolated, DNA may be obtained following in vivo excision, and the cloned insert may be sequenced in either or both orientations by art recognized methods, to identify the correct reading frame encoding a protein of the 20 appropriate molecular weight. For example, the direct analysis of the nucleotide sequence of homologous nucleic acid molecules of the present invention may be accomplished using either the dideoxy chain termination method or the Maxam Gilbert method (see Sambrook et al., Molecular Cloning, A Laboratory Manual (2nd Ed., CSHP, New York 1989); Zyskind et al., Recombinant DNA Laboratory Manual, (Acad. 25 Press, 1988)). Using these or similar methods, the protein(s) and the DNA encoding the protein may be isolated, sequenced and further characterized.

POLYPEPTIDES

[106] The invention additionally relates to isolated polypeptides obtainable from 30 the bacteriophages γ and W. The term, "polypeptide," as used herein, includes proteins,

enzymes, peptides, and gene products encoded by nucleic acids described herein. In one embodiment, the invention relates to the polypeptides encoded by the ORFs as described above in **Table 1** and **Table 2**. The invention relates to polypeptide sequences for the γ -phage and other polypeptides that may hybridize to the polypeptide sequences of the invention, including those of **FIG. 2B**. The invention further relates to polypeptide sequences for the W-phage, such as those in **FIG. 4B**, and other polypeptides that may hybridize to these sequences. Also provided in the present invention are polypeptide sequences for each ORF in **Table 1** and **Table 2**. The invention relates to polypeptides encoding Gp 14 (ORF 14 of γ -phage), Wp14 (ORF 14 of W-phage), and Wp38 (ORF 38 of W-phage). Further provided are polynucleotide sequences that hybridize to polypeptide sequences of **FIG. 2B** and **FIG. 4B**.

[107] Also included in the invention are polypeptides which are at least about 60, 70, 80, 90, and 95% identical (i.e., polypeptides which have substantial sequence identity) to the polypeptides described herein. However, polypeptides exhibiting lower levels of identity are also useful, particular if they exhibit high, e.g., at least about 90%, identity over one or more particular domains of the polypeptide. For example, polypeptides sharing high degrees of identity over domains necessary for particular activities, such as binding or enzymatic activity, are included herein. Thus, polypeptides which are at least about 10%, preferably at least about 20%, more preferably at least about 30%, more preferably at least about 40%, even more preferably at least about 50%, yet more preferably at least about 60%, still more preferably at least about 70%, yet more preferably at least about 80%, still more preferably at least about 90%, yet more preferably at least about 95%, still more preferably at least about 80% and even more preferably at least about 97% identity to the polypeptides of the invention, including SEQ ID NO:3 through SEQ ID NO:109, are encompassed by the invention.

[108] Polypeptides described herein may be isolated from naturally-occurring sources (e.g., isolated from host cells infected with bacteriophages γ and W). Alternatively, the polypeptides may be chemically synthesized or recombinantly produced. For example, PCR primers may be designed to amplify the ORFs from the

start codon to stop codon. The primers may contain suitable restriction sites for an efficient cloning into a suitable expression vector. The PCR product may be digested with the appropriate restriction enzyme and ligated between the corresponding restriction sites in the vector (the same restriction sites, or restriction sites producing the same cohesive ends or blunt end restriction sites).

[109] Polypeptides of the present invention may be used as a molecular weight marker on SDS-PAGE gels or on molecular sieve gel filtration columns using art-recognized methods. They are particularly useful for molecular weight markers for analysis of proteins from thermophilic organisms, as they will behave similarly (e.g., they will not denature as proteins from mesophilic organisms would).

[110] The polypeptides of the present invention may be isolated or purified (e.g., to homogeneity) from cell culture (e.g., from culture of host cells infected with bacteriophages γ and W) by a variety of processes. These include, but are not limited to, anion or cation exchange chromatography, ethanol precipitation, affinity chromatography and high performance liquid chromatography (HPLC). The particular method used will depend upon the properties of the polypeptide; appropriate methods will be readily apparent to those skilled in the art. For example, with respect to protein or polypeptide identification, bands identified by gel analysis may be isolated and purified by HPLC, and the resulting purified protein may be sequenced. Alternatively, the purified protein may be enzymatically digested by methods known in the art to produce polypeptide fragments which may be sequenced. The sequencing may be performed, for example, by the methods of Wilm et al. (Nature 379(6564):466-469 (1996)). The protein may be isolated by conventional means of protein biochemistry and purification to obtain a substantially pure product, i.e., 80, 95 or 99% free of cell component contaminants, as described in Jacoby, Methods in Enzymology Volume 104, Academic Press, New York (1984); Scopes, Protein Purification, Principles and Practice, 2nd Edition, Springer-Verlag, New York (1987); and Deutscher (ed), Guide to Protein Purification, Methods in Enzymology, Vol. 182 (1990).

[111] For example, representative proteins expected to be encoded by genes of bacteriophages γ and W include the following: DNA topoisomerase; exonuclease (e.g.,

3'-5' exonuclease, 5'-3' exonuclease (RNase H)); helicase; enzymes related to DNA or RNA synthesis (e.g., dCTPase, dUTPase, dCDPase, dUDPase, GTPase, dGTPase, ATPase, dATPase); transposase; reverse transcriptase; polymerase (e.g., DNA polymerase, RNA polymerase); DNA polymerase accessory protein; DNA packaging protein; DNA topoisomerase; RNA polymerase binding protein; RNA polymerase sigma factor; site-specific RNase inhibitor of protease; recombinant protein; alpha-glucosyltransferase; mobility nuclease; endonuclease (e.g., endonuclease II, endonuclease V, endonuclease VII); inhibitor of Lon protease; thymidine kinase; site-specific RNase; N-glycosidase; endolysin; lysozyme; dNMP kinase; DNA ligase; deoxyribonucleotide-3'-phosphatase; ssDNA binding protein; dsDNA binding protein; and RNA ligase.

[112] The polypeptides of the invention may be partially or substantially purified (e.g., purified to homogeneity), and/or are substantially free of other polypeptides. According to the invention, the amino acid sequence of the polypeptide may be that of the naturally-occurring polypeptide or may comprise alterations therein. Polypeptides comprising alterations are referred to herein as "derivatives" of the native polypeptide. Such alterations include conservative or non-conservative amino acid substitutions, additions and deletions of one or more amino acids; however, such alterations should preserve at least one activity of the polypeptide, i.e., the altered or mutant polypeptide should be an active derivative of the naturally-occurring polypeptide. For example, the mutation(s) may preferably preserve the three dimensional configuration of the binding site of the native polypeptide, or may preferably preserve the activity of the polypeptide (e.g., if the polypeptide is a DNA polymerase, any mutations preferably preserve the ability of the enzyme to catalyze combination of nucleotide triphosphates to form a nucleic acid strand complementary to a nucleic acid template strand). The presence or absence of activity or activities of the polypeptide may be determined by various standard functional assays including, but not limited to, assays for binding activity or enzymatic activity.

[113] Additionally included in the invention are active fragments of the polypeptides described herein, as well as fragments of the active derivatives described above. An "active fragment," as referred to herein, is a portion of polypeptide (or a

portion of an active derivative) that retains the polypeptide's activity, as described above.

[114] Homologous proteins and nucleic acids may be prepared that share functionality with such small proteins and/or nucleic acids (or protein and/or nucleic acid regions of larger molecules) as will be appreciated by a skilled artisan. Such small molecules and short regions of larger molecules, that may be homologous specifically are intended as embodiments. Preferably the homology of such valuable regions is at least 50%, 65%, 75%, 85%, and more preferably at least 90%, 95%, 97%, 98%, or at least 99% compared to the polypeptides encoded by a polypeptide sequence selected from SEQ ID NO:3- SEQ ID NO:109. These percent homology values do not include alterations due to conservative amino acid substitutions.

[115] Of course, an epitope as described herein may be used to generate an antibody and also may be used to detect binding to molecules that recognize the lysin protein. Another embodiment is a molecule such as an antibody or other specific binder that may be created through use of an epitope such as by regular immunization or by a phase display approach where an epitope may be used to screen a library if potential binders. Such molecules recognize one or more epitopes of lysin protein or a nucleic acid that encodes lysin protein. An antibody that recognizes an epitope may be a monoclonal antibody, a humanized antibody, or a portion of an antibody protein. Desirably the molecule that recognizes an epitope has a specific binding for that epitope which is at least 10 times as strong as the molecule has for serum albumin. Specific binding may be measured as affinity (K_m). More desirably the specific binding is at least 10^2 , 10^3 , 10^4 , 10^5 , 10^6 , 10^7 , 10^8 , or even higher than that for serum albumin under the same conditions.

[116] In a desirable embodiment the antibody or antibody fragment is in a form useful for detecting the presence of the lysin protein. A variety of forms and methods for their synthesis are known as will be appreciated by a skilled artisan. The antibody may be conjugated (covalently complexed) with a reporter molecule or atom such as a fluor, an enzyme that creates an optical signal, a chemilumiphore, a microparticle, or a radioactive atom. The antibody or antibody fragment may be synthesized in vivo, after immunization of an animal, for example, The antibody or antibody fragment may be

synthesized via cell culture after genetic recombination. The antibody or antibody fragment may be prepared by a combination of cell synthesis and chemical modification.

[117] Biologically active portions of a protein or peptide fragment of the
5 embodiments, as described herein, include polypeptides comprising amino acid
sequences sufficiently identical to or derived from the amino acid sequence of the
phage protein of the disclosure, which include fewer amino acids than the full length
protein of the phage protein and exhibit at least one activity of the corresponding
full-length protein. Typically, biologically active portions comprise a domain or motif
10 with at least one activity of the corresponding protein. A biologically active portion of
a protein or protein fragment of the disclosure may be a polypeptide which is, for
example, 10, 25, 50, 100 less or more amino acids in length. Moreover, other
biologically active portions, in which other regions of the protein are deleted, or added
may be prepared by recombinant techniques and evaluated for one or more of the
15 functional activities of the native form of a polypeptide of the embodiments.

[118] Appropriate amino acid alterations may be made on the basis of several
criteria, including hydrophobicity, basic or acidic character, charge, polarity, size, the
presence or absence of a functional group (e.g., --SH or a glycosylation site), and
aromatic character. Assignment of various amino acids to similar groups based on the
20 properties above will be readily apparent to the skilled artisan; further appropriate
amino acid changes may also be found in Bowie et al. (Science 247:1306-1310(1990)).
For example, conservative amino acid replacements may be those that take place within
a family of amino acids that are related in their side chains. Genetically encoded amino
acids are generally divided into four families: (1) acidic=aspartate, glutamate; (2)
25 basic=lysine, arginine, histidine; (3) nonpolar=alanine, valine, leucine, isoleucine,
proline, phenylalanine, methionine, tryptophan; and (4) uncharged polar=glycine,
asparagine, glutamine, cystine, serine, threonine, tyrosine. Phenylalanine, tryptophan
and tyrosine are sometimes classified jointly as aromatic amino acids. For example, it is
reasonable to expect that an isolated replacement of a leucine with an isoleucine or
30 valine, an aspartate with a glutamate, a threonine with a serine or a similar conservative

replacement of an amino acid with a structurally related amino acid will not have a major effect on activity or functionality.

FUSION PROTEINS

[119] The polypeptides of the invention may also be fusion polypeptides
5 comprising all or a portion (e.g., an active fragment) of the native bacteriophages γ and W polypeptide amino acid sequence fused to an additional component, with optional linker sequences. Additional components, such as radioisotopes and antigenic tags, may be selected to assist in the isolation or purification of the polypeptide or to extend the half life of the polypeptide; for example, a hexahistidine tag would permit ready
10 purification by nickel chromatography. The fusion protein may contain, e.g., a glutathione-S-transferase (GST), thioredoxin (TRX) or maltose binding protein (MBP) component to facilitate purification; kits for expression and purification of such fusion proteins are commercially available. One example of a useful fusion protein is a GST fusion protein in which the polypeptide of the disclosure is fused to the C-terminus of a
15 GST sequence. The polypeptides of the invention may also be tagged with an epitope and subsequently purified using antibody specific to the epitope using art recognized methods. Additionally, all or a portion of the polypeptide may be fused to carrier molecules, such as immunoglobulins, for many purposes, including increasing the valency of protein binding sites. For example, the polypeptide or a portion thereof may
20 be linked to the Fc portion of an immunoglobulin; for example, such a fusion could be to the Fc portion of an IgG molecule to create a bivalent form of the protein.

[120] Additionally, the nucleotide sequence(s) may be fused to a marker sequence, for example, a sequence which encodes a polypeptide to assist in isolation or purification of the polypeptide. Representative sequences include, but are not limited to,
25 those that encode a glutathione-S-transferase (GST) fusion protein. In one embodiment, the nucleotide sequence contains a single ORF in its entirety (e.g., encoding a polypeptide, as described below); or contains a nucleotide sequence encoding an active derivative or active fragment of the polypeptide; or encodes a polypeptide which has substantial sequence identity to the polypeptides described herein. In a preferred
30 embodiment, the nucleic acid encodes a polymerase (e.g., DNA polymerase); DNA

polymerase accessory protein; dsDNA binding protein; deoxyribonucleotide-3-phosphatase; DNA topoisomerase; DNA helicase; an exonuclease (e.g., 3'-5' exonuclease, 5'-3' exonuclease (RNase H)); RNA ligase; site-specific RNase inhibitor of protease; endonuclease; exonuclease; mobility nuclease; reverse transcriptase; 5 single-stranded binding protein; endolysin; lysozyme; helicase; alpha-glucosyltransferase; or thymidine kinase, as described herein. In a particularly preferred embodiment, the nucleic acid encodes a DNA polymerase, 3'-5' exonuclease, 5'-3' exonuclease (RNase H), DNA helicase or RNA ligase. In another particularly preferred embodiment, the nucleic acid encodes a DNA polymerase that lacks exonuclease 10 domains, or a 3'-5' exonuclease that lacks DNA polymerase domain, as described below.

[121] Another embodiment discloses an immunoglobulin fusion protein in which all or part of a polypeptide of the disclosure is fused to sequences derived from a member of the immunoglobulin protein family. An immunoglobulin fusion protein 15 may be incorporated into a pharmaceutical composition and administered to a subject to inhibit an interaction between a ligand (soluble or membrane-bound) and a protein on the surface of a cell (receptor), to thereby suppress signal transduction in vivo. The immunoglobulin fusion protein may alter bioavailability of a cognate ligand of a polypeptide of the disclosure. Inhibition of ligand/receptor interaction may be useful 20 therapeutically, both for treating bacterial-associated diseases and disorders for modulating (i.e. promoting or inhibiting) cell survival. Moreover, an immunoglobulin fusion protein of the disclosure may be used as an immunogen to produce antibodies directed against a polypeptide of the disclosure in a subject, to purify ligands and in screening assays to identify molecules which inhibit the interaction of receptors with 25 ligands. Chimeric and fusion proteins and peptides of the disclosure may be produced by standard recombinant DNA techniques.

[122] The acts of methods of the present invention may be done in any order, and may have other intervening steps or acts unless otherwise indicated.

[123] It is intended that the foregoing detailed description be regarded as 30 illustrative rather than limiting. The following claims, including all equivalents, that are intended to define the spirit and scope of this invention. Therefore, the embodiment

of any figure and features thereof may be combined with the embodiments depicted in other figures. Other features known in the art and not inconsistent with the structure and function of the present invention may be added to the embodiments.

[124] The recitations of “embodiments,” “one embodiment,” “some
5 embodiments,” “other embodiments,” “illustrative embodiments,” “selected
embodiments,” “certain embodiments,” and “another embodiment” herein are
synonymous. All of these recitations refer to illustrative embodiments and are not
exclusive of each other or of other embodiments not recited herein. The invention also
relates to embodiments that comprise combinations of one or more of the illustrative
10 embodiments described above.

[125] All references cited herein are hereby incorporated into this disclosure in
their entirety.

[126] The following Examples are offered for the purpose of illustrating the
present invention and are not to be construed to limit the scope of this invention. The
15 teachings of all references cited are hereby incorporated herein by reference in their
entirety.

EXAMPLES

[127] Example 1: Isolation of polynucleotides of γ and *W* bacteriophages

[128] The *B. anthracis* strain used in this study lacks the pXO1 and pXO2
20 virulence plasmids (Δ sterne), while the *B. cereus* strain used, RSVF1, is an American
Type Culture Collection (ATCC) reference strain that is largely genetically indistinct
from *B. anthracis* and transition state *B. cereus*. Initially, we determined whether
RSVF1 represents a transition strain (or derivative thereof, as it is a laboratory passaged
strain) by looking for *B. anthracis* features either shared by or lacking in the transition
25 strains. Like *B. anthracis*, RSVF1 was non-motile, sensitive to the γ lysine, grew in
chains, was virulent in mice, and encoded the *csa* operon (products of which modify
B. anthracis surface carbohydrate), the *Ba813* locus (diagnostic marker for *B. anthracis*
and transition state *B. cereus*), and a specific 12 base pair tandem repeat array within
vrnA (characteristic of certain *B. anthracis* isolates). Unlike *B. anthracis*, but like
30 transition *B. cereus*, RSVF1 lacked pXO1 and pXO2, and had a functional PlcR

transcriptional regulator (inactive in *B. anthracis* owing to a single nonsense mutation.). Prophage content differed as well, based on findings that a) PCR analyses of several distinct *B. anthracis* prophage genes yielded no amplification products with RSVF1, and b) long-range repetitive PCR using primers specific for a phage attachment site
5 detects gross genetic polymorphisms between *B. anthracis* and transition state *B. cereus*. RSVF1 does, therefore, represent transition state *B. cereus*, largely distinguished from *B. anthracis* by the absence of plasmid and phage elements.

[129] The γ phage was isolated as variant of W that had a more *B. anthracis*-specific host range (though still infecting transition state *B. cereus*) and, unlike W,
10 infected both encapsulated and unencapsulated bacilli. As such, γ became an important tool for rapid confirmatory clinical diagnosis of *B. anthracis* still in widespread use.

[130] A majority of the γ phage genome (~95%) was sequenced by Genome Therapeutics Corporation (Waltham, MA) using a library of 3.0-3.5kb fragments as templates. This analysis was performed using ABI dye terminator chemistry on
15 automated MegaBace 1000 (Amersham) machines. Base calls and quality scores were determined using the PHRED program (Ewing and Green, 1998 Genome Res. 8:186-194) and reads were assembled by using PHRAP with default program parameters and quality scores. Closure of numerous gaps and determination of the phage termini were accomplished at The Rockefeller University using a primer walking method and
20 purified γ DNA as template. At The Rockefeller University samples were thermocycled in an ABI GeneAmp PCR System 9600/9700 and the purified extension products were electrophoresed on an ABI Prism 3700 DNA Analyzer. Sequence data was assembled into a completed contig using the SeqMan program (DNASTAR software package). Putative ORFs were determined by both ORF Finder
25 (www.ncbi.nlm.nih.gov) and GeneMark approach of gene prediction (http://opal.biology.gatech.edu/GeneMark/gmhmm2_prok.cgi). The BLAST algorithms, available through NCBI, were used for similarity searches of putative ORFs.

[131] The W phage genome was sequenced completely at The Rockefeller
30 University using a primer walking method. Primer construction was completely based

on the γ phage genomic sequence. Sequence was assembled, annotated and analyzed in the same manner used for the γ genome.

[132] Example 2: Binding of GFP Fusion Proteins

[133] GFP-PlyG – binds *Bacillus anthracis* (“Ba”) in a whole cell manner (**FIG. 6A**), RSVF1 only a polar positions (**FIG. 6B**). Rare RSVF1 derivatives bind whole cell (**FIG. 6C**).

[134] GFP-Gp14 – whole cell binding with Ba (**FIG. 6D**) and polar with RSVF1 (**FIG. 6E**). Ba lysogenized with W is now polar (**FIG. 6F**). Indicates that phage affect alteration in surface distribution of receptor, likely carbohydrate. This is a major change in *B. anthracis* phenotype associated with W phage infection. Either directly affects carbohydrate structure (W does encode a gene involved in sugar conversion to mannose, a known component of the Ba carbohydrate) or indirectly via a transcriptional regulatory factor.

[135] GFP-PlyG binding (or presumably Gp14) may be used as a diagnostic tool...shows that when Ba is diluted 10,000 fold in a culture of *B. cereus* 10987, it is still readily identifiable by fluorescence (**FIG. 6G, FIG. 6H**). The speed of this binding (seconds) and difficulty in washing it away (can stand up to >5 washes in PBS) suggests that GFP-PlyG may be used as a part of a Ba diagnostic method.

[136] Example 3: Effects of Ivsogeny with W on RSVF1 and B. anthracis

20 [137] Effect on RSVF1:

[138] No alteration in % sporulation, hemolysis, extracellular lipase or protease secretion, motility or colony morphology. Did notice two main changes, however.
1) The strain no longer grows as a filamentous form, but as a rod shape (**FIG. 7A, FIG. 7B**). 2) the spore structure is altered. The spore has a more mottled or textured appearance by SEM (compared to parental non-lysogen) (**FIG. 7C, FIG. 7D**). By negative staining TEM, there is no difference in exosporial structure or surface components. There is however, a change in the coat structure. The coat is more osmophillic and consist on multiple darkened outer layers, with surface knob-like extensions or striations (**FIG. 7E, FIG. 7F**).

30 [139] Effect on B. anthracis:

[140] No alteration in % sporulation, motility, colony morphology or shape. However, the strain is now alpha hemolytic. Infection has activated a cryptic hemolysin. Transcriptional activators in the W phage are likely responsible. A hallmark of Ba is its lack of hemolysis, despite having hemolysin. The lysogen
5 definitely now has hemolytic activity on plates. A quantitative analysis was performed based on a technique described by Mignot et al. 2001 (Mol Microbiol 42:1189) in which the lysogen had 64 units of activity and the parental strain (no phage) had 0 units. The lysogen is also weakly but definitely activated for extracellular protease and lipase activity on plates. These features are all more Bc like. An entire regulon of
10 extracellular activities is encoded in both Ba and Bc, however, they are only expressed in Bc (repressed in Ba) due to a point mutation in a transcriptional regulator PlcR in Ba. What we see here is the weak activation of this Bc-like regulon in Ba. Either a phage transcriptional regulator is doing this, or the phage integration is activating some downstream regulator.

15 [141] Example 4 Gp14 ORF used with primers

[142] The entire *gp14* ORF was PCR amplified with primers flanking the 1.5 kb locus, using purified γ phage genomic DNA as template. The primers used were as follows:

[143] 5' ACAGATATCTTGGGGAAACTTAGTTTTACTT 3' (SEQ ID NO:110)

20 [144] 5' CCCAAGCTTTCATCTATATCTCTCCCTATAACTGA 3' (SEQ ID NO:111)

[145] The *EcoRV* and *HindIII* 'sticky ends' were used to clone the 1.5 kb amplification product at the 3' end of *gfpmut2* (GenBank nucleotide accession number AF302837) in plasmid pBAD24::*gfp* digested with *SmaI* and *HindIII*. The reference
25 for pBAD24 is Guzman et al., 1995 J. Bacteriol. 177:4121-4130. The reference for the *gfpmut2* is Cormack et al., 1996 Gene 173:33-38. The cloning described above yields a *gfpmut2*-*gp14* translational fusion. The *gfpmut2*-*gp14* construct was excised with *EcoRI*-*HindIII* and cloned into the *EcoRI*-*HindIII* sites of the vector pBAD/His (Invitrogen). This creates an in frame His tagged fusion, which was subsequently
30 purified by affinity chromatography. The purified His-GFP-Gp14 fusion protein was

used to label both *B. cereus* 4342 and *B. anthracis* Δ sterne. Exponential phase bacteria growing in BHI media were washed with PBS and concentrated 10 fold and fixed in a 3% formalin in PBS solution for 20 minutes at room temperature. A 100 μ l aliquot was then incubated with 100 μ l of the GFP fusion protein for 5 minutes at 4C. The cells
5 were washed with PBS, mounted in SlowFade (Molecular Probes, Inc.), and examined by fluorescence microscopy.

[146] The His-GFP-PlyG fusion protein was constructed, purified, and analyzed in the exact same manner, with the exception that the plyG ORF was amplified with the following primers:

10 [147] 5' gaagatatcatgttcagtaatggaaatcca 3' (SEQ ID NO:112)

[148] 5' accaagctttatttaacttcataccaccaac 3' (SEQ ID NO:113)

[149] Prophetic Example 5: Use of Wp38 as a means to deliver antigens to the *B. anthracis* spore surface.

15 [150] This may be used for vaccine delivery of an anthrax antigen delivered to the surface of an anthrax spore resulting in a vaccine that may protect against both vegetative anthrax and its spores. Wp38 is encoded in the W phage and is similar to a family of spore surface proteins encoded within the *B. anthracis* and *B. cereus* genomes. It is likely expressed from a sporulation-specific promoter and is integrated
20 into the spore exosporium facing the extracellular environment. Since it is not essential for spore formation and resistance properties, we may modify the wp38 sequence, through fusions to exogenous proteins, thereby effecting delivery of the exogenous proteins to the spore surface.

[151] Prophetic Example 6: Use of the W lysogenic phage as a means to deliver
25 novel DNA sequences to the *B. anthracis* genome, and to express those sequences.

[152] Since the W phage genome is stably maintained in *B. anthracis*, we may genetically modify the phage (ie, insert genes of interest) and allow the recombinant phage to infect and be maintained within the bacterium. If the inserted gene is cloned downstream of an inducible promoter also engineered into the W phage, then an
30 expression system is established. We may thus express foreign genes of interest within

B. anthracis. Expression may be induced either during vegetative growth or during sporulation. With the addition of signal peptide-encoding sequences to the foreign gene, their protein products may be directed to the vegetative cell surface, or into the bacterial supernatant.

5 [153] Prophetic Example 7: Use of the W or gamma phages as tools for intact phage therapy.

[154] Even though we are not involved in phage therapy, those interested could use these phage in their application. Highly purified phage stocks may be used either alone, or in combinations with other *B. anthracis*-specific phage to kill and clear *B.*
10 *anthracis* during systemic anthrax infections. This therapy may be performed alone or in conjunction with antibiotic and/or anti-toxin treatment. The phage stocks may also be used to kill or clear *B. anthracis* from contaminated environmental surfaces or from production facilities.

[155] Example 8: Use of the gamma or W phage tail protein (Gp14 and Wp14, respectively) as a tool to detect *B. anthracis* in environmental or clinical samples as a diagnostic.

[156] A Gp14 fusion with GFP has been constructed and shown to specifically bind the surface of *B. anthracis* and relate to a detectable fluorescent signal. This binding is rapid, requiring incubation of the fusion protein and bacteria for only 1
20 minute. This binding is specific, as it may be used to readily detect a fluorescing *B. anthracis* rod among a background of non *B. anthracis* bacilli, where the *B. anthracis* is diluted 1:10,000.

[157] Example 9: Study of the Specificity of γ -phage for *B. anthracis* and strength of γ -phage

25 [158] The gamma phage was isolated from *Bacillus anthracis* and was obtained from Hans W. Ackermann (Laval University, Quebec, Canada). Phage susceptibilities were initially tested by adding 10 ml of high titer gamma aliquots to fresh lawns of strains indicated in Table 1; clearance after 16 h growth indicated susceptibility. A high titer phage stock containing 2.2×10^{10} plaque forming units (pfu) ml⁻¹ was prepared
30 using RSVF1 by a previously described method (Loeffler, J. M., Nelson, D. &

Fischetti, V. A. Rapid killing of *Streptococcus pneumoniae* with a bacteriophage cell wall hydrolase. Science 294, 2170-2 (2001)). A pfu is a single phage that forms a small clearing zone, or plaque, after successive rounds of infection, growth, and release on lawns of susceptible bacteria. The RSVF1-derived phage stock was used in titer determinations.

[159] To study the specificity and strength of the gamma phage and the resulting lytic enzyme, different strains of *Bacillus* were prepared. Most strains were grown at 30°C in Luria broth (LB) or brain-heart infusion broth (BHI), supplemented with 1.5% agar when needed. Analyses involving *E. coli* XL1-Blue (Stratagene) were performed at 37°C, while *B. stearothermophilis* was handled at 55°C. Strain RSVF1 is a streptomycin resistant derivative of *B. cereus* reference strain ATCC 4342. Despite the similarities between RSVF1 and *Bacillus anthracis*, important genotypic differences exist, and RSVF1 is not a misidentified *Bacillus anthracis* stain (Pannucci, J., Okinaka, R. T., Sabin, R. & Kuske, C. R. *Bacillus anthracis* pXO1 plasmid sequence conservation among closely related bacterial species. J Bacteriol 184, 134-41 (2002); Helgason, E., Caugant, D. A., Olsen, I. & Kolsto, A. B. Genetic structure of population of *Bacillus cereus* and *B. thuringiensis* isolates associated with periodontitis and other human infections. J Clin Microbiol 38, 1615-22 (2000); Ticknor, L. O. et al. Fluorescent Amplified Fragment Length Polymorphism Analysis of Norwegian *Bacillus cereus* and *Bacillus thuringiensis* Soil Isolates. Appl Environ Microbiol 67, 4863-73 (2001)). Analysis of the *vrrA* locus of RSVF1 was performed as described (Jackson, P. J. et al. Characterization of the variable-number tandem repeats in *vrrA* from different *Bacillus anthracis* isolates. Appl Environ Microbiol 63, 1400-5 (1997)). *Bacillus anthracis* manipulations were provided by Leonard W. Mayer (Centers for Disease Control, Atlanta, Georgia) and Abraham L. Turetsky (Aberdeen Proving Grounds, Aberdeen, Maryland). These bacterial strains were then exposed to gamma phage.

[160] Example 10: studies with the lysin produced by the γ -phage

[161] It was found that RSVF1 was sensitive to infection by γ -phage, and exhibited matt colony morphology, a filamentous structure, and repetitive sequences in the

hypervariable *vrrA* locus which are all characteristic of *Bacillus anthracis*. The lytic activity of PlyG (the gamma lysin produced by gamma phage) was examined by exposing a panel of the indicated liquid bacterial cultures to either PlyG (20 units) or phosphate buffer. The fold killing represents the decrease in bacterial viability determined 15 minutes post-lysing compared to the buffer treatment. The “Bc” and “Bt” prefixes indicate strains as either *B. cereus* or *B. thuringiensis*, respectively. RSVF1 has no virulence plasmids, but is nonetheless highly related to *Bacillus anthracis* and a suitable gamma phage host.

[162] A phenotypic screen was used to identify gamma phage proteins that lyse RSVF1 “from without.” An induced gamma phage expression library in an *E. coli* background was permeabilized and overlaid with a RSVF1 lawn. gamma genomic DNA was isolated using the l Maxi kit of Qiagen Inc. 5 mg aliquots of gamma DNA were partially digested with Tsp509I and cloned fragments ranging from 0.5-3.0 kb into the EcoRI site of the arabinose-inducible expression vector pBAD24. The resulting expression library was then transformed into *E. coli* XL1-Blue and screened for lysin activity on glass LB plates containing 100 mg ml⁻¹ ampicillin and 0.25% arabinose. The induced library was permeabilized with chloroform vapors and overlaid with exponential phase RSVF1 in 0.75% LB agar. After a 24 h incubation, distinct clearing, or lytic, zones were identified over library members. Corresponding plasmid DNA was prepared and sequenced. DNA sequence analysis and manipulations required the BLASTP (NCBI), ORF finder (NCBI), and SeqMan 5.0 (Dnastar Inc.) programs.

[163] One of the pBAD24::plyG constructs recovered in the library search and encoding only the plyG ORF was used as a source of recombinant PlyG. Expression was induced with 0.25% L-arabinose in an overnight LB culture supplemented with ampicillin 100 mg ml⁻¹. Cells were washed, resuspended in 50 mM Tris, pH 8.0, and lysed with chloroform added to a concentration of 16.6%. Cellular debris and chloroform were removed by centrifugation, yielding the crude PlyG supernatant. The cationic nature of PlyG enabled it to pass through a HiTrap Q Sepharose XL column (Amersham Biosciences), which bound to most contaminants. The enzyme was further purified by application to a Mono S HR 5/5 column (Amersham Biosciences) and elution in a linear gradient containing 1 M NaCl. Active fractions were pooled and

purity was assessed by gel electrophoresis and chromatography on a Superose 12 column (Amersham Biosciences) equilibrated with gel filtration standards (Bio-Rad).

[164] Clones that yielded lytic zones all contained a 702 bp gamma ORF encoding a product homologous to lysins called N-acetylmuramoyl-L-alanine amidases. TP21 and f 105 indicate *B. cereus* and *B. subtilis* phage amidases, respectively. CwlA and ClyA are encoded in the *B. cereus* and *B. subtilis* genomes, respectively. The dark shading represents sequence identity and the lighter shading represents similarity.

Homology is restricted to their catalytic NH₂-terminal halves, and absent in the lysin-specific COOH-terminal binding domains. Recombinant gamma lysin (called PlyG, for phage lysin gamma) was purified to homogeneity by column chromatography using Coomassie Blue-stained, SDS-Page of purified PlyG. The molecular mass was estimated based on the positions of Kaleidoscope (Bio-Rad) standards that are not shown. The N-terminal sequence of this band corresponds to the predicted PlyG sequence. Gel filtration confirmed a predicted size of ~27 kDa, and suggests that PlyG acts as a monomer and is not proteolytically processed.

[165] Example 11: In Vitro Lysin Activity

[166] Activity was examined in several ways. A Spectramax Plus 384 spectrophotometer (Molecular Devices) was used to follow the drop in OD₆₅₀ of logarithmic phase RSVF1 incubated for 15 min at 37°C with serial dilutions of purified PlyG. Enzyme activity in units ml⁻¹ was then determined as described (Nelson, D., Loomis, L. & Fischetti, V. A., Prevention and elimination of upper respiratory colonization of mice by *group A streptococci* by using a bacteriophage lytic enzyme. Proc Natl Acad Sci U S A 98, 4107-12 (2001)). It was estimated that 1 unit of enzyme corresponded to 1 mg of PlyG. A crude measure of lysin specificity was performed in which 10 ml drops of purified PlyG (0.5 units) were applied to fresh lawns derived from the indicated strains. After overnight incubation, the appearance of clearing zones was used to assess activity. A liquid killing assay was also used, in which 1.0 ml of logarithmic phase cells (~1.0 x 10⁸ cells) was treated with the indicated amounts of PlyG for 15 min at 37°C; at the indicated time points, samples were removed, washed to remove lysin, and plated for enumeration. As a measure of PlyG-directed lysis, ATP released from dying cells was indirectly measured in a reaction containing a

luciferin/luciferase reagent and a micro luminometer (PROFILE-1 reagent kit and model 3550i luminometer, New Horizons Diagnostics Corp.) according to the manufacturers protocol. In brief, vegetative cells of the indicated strains were immobilized on 0.45 μ M filters at the base of a 0.4 ml reaction chamber. The immobilized cells were
5 washed twice with somatic cell releasing agent to remove impurities and 0.1 ml of PlyG in phosphate buffer was added for 2 min. 0.05 ml of the luciferin/luciferase reagent provided with the kit was added and immediately assayed at room temperature for 10 sec. All samples were tested five times. The relative light units released by RSVF1 were consistently ten to twenty percent of its total releasable light (as determined using
10 a strong detergent mixture provided with the kit).

[167] RSVF1 was as sensitive to PlyG killing as a set of *Bacillus anthracis* isolates from America, Europe, Asia and Africa (13). *B. cereus* 10987, a rare strain closely related to *Bacillus anthracis*, was slightly susceptible to PlyG, while all other strains examined were resistant. Helgason, E. et al. *Bacillus anthracis*, *Bacillus cereus*, and
15 *Bacillus thuringiensis*--one species on the basis of genetic evidence. Appl Environ Microbiol 66, 2627-30 (2000). A more sensitive test of PlyG-mediated killing was evaluated in buffer containing $\sim 5.0 \times 10^7$ bacteria and treated with 20 units of PlyG for 15 min. RSVF1 was reduced $>1.6 \times 10^7$ -fold, while ATCC 10987 was reduced ~ 100 fold. Other strains examined were largely resistant, even after a three-hour incubation.
20 PlyG may clearly direct a potent and specific lethal action to the *Bacillus anthracis* cluster, exhibiting a substrate specificity that closely matches the gamma phage host range. Moreover, the capsulated state of several *Bacillus anthracis* strains examined, indicated that capsule does not block access of PlyG to the cell wall.

[168] It was found that PlyG, like most lysins, is a very active enzyme. The
25 addition of 2 units of PlyG to $\sim 1.0 \times 10^4$ RSVF1 caused an immediate release of intracellular ATP (measured as light emitted by firefly luciferin/luciferase), which is consistent with a rapid lytic effect. This effect was specific for RSVF1, and was not observed in other isolates tested, therefore suggesting that the ATP release assay is a strong diagnostic tool for g-sensitive bacilli. In a separate kinetic analysis of RSVF1
30 killing, it found that as little as 2 units of PlyG effected a 1.7×10^4 -fold decrease in viability within 20 sec, and sterilization at 2 min. Here the time course of RSVF1

killing in cultures was treated with buffer (r) or 1 unit of PlyG (™). These values are shown as colony forming units per ml of culture determined at each time point. The corresponding OD₆₀₀ determined for the PlyG-treated sample (Î) is shown. The loss of culture optical density lagged behind the loss in viability, implying that killing by PlyG does not necessarily require extensive cell wall degradation.

[169] Example 12: Microscopy

[170] To visually examine the lytic effect phase contrast microscopy of PlyG-treated RSVF1 was used. It was found that the normally filamentous RSVF1 rapidly converts to short rod- and minicell-like forms 30 sec after exposure; nearly complete loss of cytoplasmic material occurs by 15 min, leaving “ghost” cells. Transmission electron microscopy of the rod forms reveals the cytoplasmic membrane bulging from regions of localized cell wall hydrolysis. These structures are usually apparent at polar and septal positions, and rupture to yield a ghost-like form.

[171] Example 13: In Vivo Lysin Activity

[172] The lytic effect of PlyG suggested it could be used to kill g-sensitive bacteria in a mouse model of infection. Four- to eight-week old BALB/c female were purchased from Charles River Laboratories and housed at the Laboratory Animal Research Center at The Rockefeller University. Mouse infections were performed as a variation of a previously described procedure. Log phase RSVF1 grown in BHI medium, was pelleted and washed twice in 50 mM K₂PO₄ buffer (pH 7.4). Aliquots of ~1.0 x 10⁶ cells in buffer were injected intraperitoneally (i.p.) into mice in 0.1 ml doses. After 15 min, 0.5 ml of either buffer alone or PlyG in buffer were injected into the peritoneal cavity. Injections of PlyG alone (no bacteria) were also performed to assess toxicity. Mice were monitored for up to 3-4 days, at which time all surviving mice had recovered a normal and unremarkable appearance.

[173] The i.p. injection of some *B. cereus* isolates may induce a rapidly fatal illness similar to experimental anthrax. The injection of ~1.0 x 10⁶ RSVF1 cells into BALB/c mice, killed all subjects in five hours or less. More specifically, mice were injected i.p. with ~1.0 x 10⁶ RSVF1 cfu and treated after 15 min with either phosphate buffer (n=15), 50 U PlyG (n=17), or 150 U PlyG (n=9). As an additional control, mice that were not challenged with bacteria were injected with 50 U PlyG (n=5). The

experiment was terminated at 72 hours. Administration of either 50 U or 150 U to the infected mice was significantly protective compared to the buffer control ($P < 0.0001$). The median survival time for the buffer treated mice was 2 hours. At death, many mice exhibited severe edema at the inoculation site, and hemorrhaging through the eyes and mouth. When PlyG (50 units) was injected i.p. 15 min post-infection, a pronounced therapeutic effect was observed: thirteen of nineteen mice fully recovered, while the remainder survived six to twenty-one hours. When 150 units of PlyG were used, a similar rate of recovery was observed. No toxicity was detected with either the i.p. or i.v. injection of PlyG alone. PlyG does, therefore, rapidly kill g-sensitive bacteria in an infected animal.

[174] The ability of PlyG to degrade germinating spores was examined next. Spores were prepared as described in Mazas, M., Martinez, S., Lopez, M., Alvarez, A. B. & Martin, R. Thermal inactivation of *Bacillus cereus* spores affected by the solutes used to control water activity of the heating medium. Int J Food Microbiol 53, 61-7 (1999). Samples containing 95-99% refractile endospores, as determined by phase contrast microscopy, were stored at 4°C in water. For spore killing experiments, 0.2 ml aliquots of $\sim 2.0 \times 10^8$ spores were heat activated at 65°C for 5 min. Samples were pelleted and suspended in 1.0 ml tryptic soy broth (TSB, Difco) containing 100 mM L-alanine (to induce germination) for 5 min at 37°C. The cells were then treated with 1.0 ml of PlyG (10 units) for 5 min at 37°C and plated for enumeration. TSB with L-alanine is a potent inducer of germination for each spore type, converting >99% of each spore type used to heat sensitive forms within 15 min. In the presence of D-alanine, germination frequency was reduced to <10%.

[175] Example 14: Spore detection

[176] For spore detection, the spore killing protocol was modified for use with a microluminometer (model 3550i, New Horizons Diagnostics Corp.). Essentially, 0.1 ml of heat-activated spores (65°C, 5 min) were immobilized on a 0.45 mM filter in the 0.4 ml reaction tube. The immobilized spores were washed twice with somatic cell releasing agent and treated with 0.15 ml TSB with 100 mM L-alanine for 5 min at room temperature. Samples were then washed and treated with 0.15 ml PlyG (2 units) for 5 min at room temperature. 50 ml of a luciferin/luciferase reagent was added for the

indicated length of time and a quantitative measure of the resulting light, given as relative light units, was displayed by the luminometer. In the dormant state, the spore's peptidoglycan, or cortex, is protected from lysozymes and amidases by a proteinaceous coat. However, within 10 min of inducing germination, coat porosity increases as it begins to degrade; it was reasoned that subjacent peptidoglycan may be rendered susceptible to PlyG.

[177] To evaluate this, spores were prepared from RSVF1, closely related *B. cereus* (ATCC 14579) and *B. thuringiensis* (ATCC 33679) strains, and *B. subtilis*. Aliquots of ~10⁸ heat activated spores were induced to germinate for 5 min and then treated with PlyG (10 units) for 5 minutes. Resulting spore viability was compared to that of spores treated with D-alanine, a germination inhibitor. While all D-alanine-treated spore samples were PlyG-resistant, only RSVF1 was sensitive after germination in the presence of L-alanine., showing a dramatic decrease in viability of log₁₀ 3.9. A sporocidal action, therefore, occurs rapidly after the induction of germination, when PlyG may likely access the cortex. In light of the thickness of the cortex, the rapid PlyG effect suggests a subtle alteration impairing spore outgrowth, rather than a massive degradative action.

[178] The ability of PlyG to kill germinating spores was exploited to develop a rapid and specific system for detecting g-sensitive spores using a hand-held luminometer. Spores were immobilized or placed on filters or in cuvettes (in a solution) and incubated in at least one 5 min round with at least one germinant and PlyG (2 units). The temperature at which the incubation took place was from room temperature to 60 degrees Centigrade. The spores could be incubated first in germinant and then in PlyG or with the germinant and PlyG together. The phage associated lytic enzyme does not have to be PlyG but must be specific for the spore being tested. The release of ATP from degrading spores was then measured as a light "flash" emitted in the presence of a luciferin/luciferase reagent. ATP released from PlyG-treated germinating spores was assessed in the presence of luciferin/luciferase. 2.5 x 10³ RSVF1 spores were induced to germinate with L-alanine and treated with 2 units of PlyG. The PlyG-mediated flash was measured. Germinating spores of Bc 14579, Bt 33679, and *B. subtilis* showed no activity, demonstrating the expected recognition

specificity of PlyG. Not surprisingly, when spore preparations were mixed, only the combination containing RSVF1 yielded a light signal. Samples containing 2.5×10^3 spores of Bc 14579, Bt 33679, and *B. subtilis* with (RSVF+ mix) or without (RSVF1-mix) RSVF1 were induced to germinate in L-alanine. The intensity of luminescence after PlyG treatment (2 units) was measured. The sensitivity of our system was examined using samples containing as few as ~100 spores. Rather than an immediate light flash, an RSVF1 signal was observed after 60 min incubation in the presence of PlyG and the luciferin/luciferase reagent. This signal is consistent with a low-level “glow,” and is consistent with the low levels of ATP likely being released. No glow was detected in the presence of other germinating spore types, and is, therefore, specific to the g-sensitive spores. This sensitivity, combined with the specificity, rapidness, and highly portable nature of our detection method, suggests applications in monitoring both domestic and battlefield use of *Bacillus anthracis* as a biological weapon. This technique may be used to identify the presence of spores from other bacterial species using bacteriophage lysins specific for those species.

[179] The phage associated enzyme used to lyse the *Bacillus anthracis* spores may be a lytic enzyme, chimeric lytic enzymes, shuffled lytic enzymes, and combinations thereof. The phage associated lytic enzyme, and its altered forms, may be the PLV gamma enzyme, or another phage associated lytic enzyme specific for *Bacillus anthracis*.

[180] A holin protein may also be used to assist in the lysing of the germinating spores. The holin protein may be unaltered, chimeric, shuffled, or may be combinations, thereof.

[181] The nature of the luminometer that may be used for the detection of ATP, and its method of use is found and described in U.S. Pat. 6,395,504 (herein incorporated by reference).

[182] Example 15: Mutagenesis and screening for resistance

[183] Spontaneous lysin resistance was initially examined as described (Loeffler, et al.) by repeated exposure to PlyG at low concentrations on agar plates or to increasing concentrations in liquid assays. No resistance was detected.

[184] To determine if spontaneous resistance was at all possible, chemically mutagenized cells were examined. Log phase RSVF1 was treated for 4 hours with methanesulfonic acid ethyl ester (EMS) at a concentration of 150 mM, resulting in 90% killing. The cells were then washed with BHI and grown 3 h (three cell doublings) prior to freezing at -70°C. The efficiency of mutagenesis was estimated by the frequency of mutations giving resistance to 150 mg ml⁻¹ streptomycin (strep^R) or to 3.5 mg ml⁻¹ novobiocin (nov^R). The spontaneous frequencies in non-mutagenized cultures were 2.4 x 10⁻⁹ for strep^R and 4.0 x 10⁻¹⁰ for strep^R; for EMS treated RSVF1 the frequencies were 2.1 x 10⁻⁶ for strep^R and 4.3 x 10⁻⁶ for strep^R. For screening, frozen mutagenized cells were then thawed, washed in BHI, and grown for 30 min at 30°C. One milliliter aliquots (~1.0 x 10⁸ cells) were incubated with PlyG for 30 min at 37°C, washed, and either plated or incubated overnight in BHI. Colonies arising from the plated cells were picked and evaluated for resistance to 20 units of PlyG in the spectrophotometric lysin assay. For the overnight BHI cultures, log phase cells were established and ultimately treated again with PlyG as before; this was repeated for 4 successive days. In one set of experiments, 20 units of PlyG was used for each treatment, while in another 0.05 units was used and followed by serial 10-fold higher doses on following days. Bacteria were plated after each treatment, and later examined for resistance to 20 units of PlyG in the spectrophotometric lysin assay. No resistance was detected.

WE CLAIM:

1. An isolated polynucleotide selected from the group consisting of:
 - (a) a polynucleotide of SEQ ID NO:1,
 - 5 (b) a polynucleotide with at least 60% identity to the polynucleotide sequence of SEQ ID NO:1, and
 - (c) a polynucleotide of SEQ ID NO:1, with up to 50 conservative nucleotide substitutions;wherein the isolated polynucleotide encodes a polypeptide that infects *B. anthracis*.
- 10 2. An isolated polynucleotide having at least 70% identity to the polynucleotide sequence of SEQ ID NO:1.
3. The isolated polynucleotide of claim 2, wherein the isolated polynucleotide has at least 80% identity to the polynucleotide sequence of SEQ ID NO:1.
4. The isolated polynucleotide of claim 2, wherein the isolated polynucleotide has at least 90% identity to the polynucleotide sequence of SEQ ID NO:1.
- 15 5. The isolated polynucleotide of claim 1, wherein the isolated polynucleotide encodes a polypeptide that specifically binds to *B. anthracis* and RSVF1.
6. The isolated polynucleotide of claim 1, wherein the isolated polynucleotide encodes a polypeptide that specifically binds to *B. anthracis* and RSVF1 at a level of 100 PFU/ml or greater, but binds to other *B. cereus* bacteria at a level of less than 100 PFU/ml.
- 20 7. An isolated nucleic acid comprising an open reading frame of SEQ ID NO:1.
8. An isolated nucleic acid consisting of the sequence of SEQ ID NO:1.
9. An isolated nucleic acid comprising the coding sequence of SEQ ID NO:1.
- 25 10. A DNA construct comprising an isolated nucleic acid molecule comprising the nucleotide sequence of an open reading frame of SEQ ID NO:1, operatively linked to a regulatory sequence.

11. An isolated nucleic acid molecule comprising at least 50 contiguous nucleotides of SEQ ID NO:1.
12. An isolated nucleic acid molecule comprising the contiguous nucleotides of an open reading frame from SEQ ID NO:1, with up to 50 conservative nucleic acid substitutions.
13. An isolated nucleic acid that hybridizes under high stringency conditions to the coding sequence of SEQ ID NO:1, wherein said nucleic acid encodes a polypeptide that infects *B. anthracis*.
14. The isolated nucleic acid of claim 12, wherein the nucleic acid is at least 15 nucleotides in length.
15. An isolated nucleic acid selected from the group consisting of:
 - (a) a nucleic acid sequence encoding a polypeptide selected from the group consisting of: SEQ ID NO:3, SEQ ID NO:5, SEQ ID NO:7, SEQ ID NO:9, SEQ ID NO:11, SEQ ID NO:13, SEQ ID NO:15, SEQ ID NO:17, SEQ ID NO:19, SEQ ID NO:21, SEQ ID NO:23, SEQ ID NO:25, SEQ ID NO:27, SEQ ID NO:29, SEQ ID NO:31, SEQ ID NO:33, SEQ ID NO:35, SEQ ID NO:37, SEQ ID NO:39, SEQ ID NO:41, SEQ ID NO:43, SEQ ID NO:45, SEQ ID NO:47, SEQ ID NO:49, SEQ ID NO:51, SEQ ID NO:53, SEQ ID NO:55, SEQ ID NO:57, SEQ ID NO:59, SEQ ID NO:61, SEQ ID NO:63, SEQ ID NO:65, SEQ ID NO:67, SEQ ID NO:69, SEQ ID NO:71, SEQ ID NO:73, SEQ ID NO:75, SEQ ID NO:77, SEQ ID NO:79, SEQ ID NO:81, SEQ ID NO:83, SEQ ID NO:85, SEQ ID NO:87, SEQ ID NO:89, SEQ ID NO:91, SEQ ID NO:93, SEQ ID NO:95, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, and SEQ ID NO:107; and
 - (b) a nucleic acid sequence encoding a polypeptide selected from the group consisting of: a nucleic acid sequence encoding a polypeptide selected from the group consisting of: SEQ ID NO:3, SEQ ID NO:5, SEQ ID NO:7, SEQ ID NO:9, SEQ ID NO:11, SEQ ID NO:13, SEQ ID NO:15, SEQ ID NO:17, SEQ ID NO:19, SEQ ID NO:21, SEQ ID NO:23, SEQ ID NO:25, SEQ ID NO:27, SEQ

5 ID NO:29, SEQ ID NO:31, SEQ ID NO:33, SEQ ID NO:35, SEQ ID NO:37,
SEQ ID NO:39, SEQ ID NO:41, SEQ ID NO:43, SEQ ID NO:45, SEQ ID
NO:47, SEQ ID NO:49, SEQ ID NO:51, SEQ ID NO:53, SEQ ID NO:55, SEQ
ID NO:57, SEQ ID NO:59, SEQ ID NO:61, SEQ ID NO:63, SEQ ID NO:65,
SEQ ID NO:67, SEQ ID NO:69, SEQ ID NO:71, SEQ ID NO:73, SEQ ID
NO:75, SEQ ID NO:77, SEQ ID NO:79, SEQ ID NO:81, SEQ ID NO:83, SEQ
ID NO:85, SEQ ID NO:87, SEQ ID NO:89, SEQ ID NO:91, SEQ ID NO:93,
SEQ ID NO:95, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID
NO:103, SEQ ID NO:105, and SEQ ID NO:107, lacking its associated signal
10 peptide.

16. An isolated nucleic acid that hybridizes under high stringency conditions to:

(a) a nucleic acid sequence encoding a polypeptide selected from the group
consisting of: a nucleic acid sequence encoding a polypeptide selected from the
group consisting of: SEQ ID NO:3, SEQ ID NO:5, SEQ ID NO:7, SEQ ID
15 NO:9, SEQ ID NO:11, SEQ ID NO:13, SEQ ID NO:15, SEQ ID NO:17, SEQ ID
NO:19, SEQ ID NO:21, SEQ ID NO:23, SEQ ID NO:25, SEQ ID NO:27, SEQ
ID NO:29, SEQ ID NO:31, SEQ ID NO:33, SEQ ID NO:35, SEQ ID NO:37,
SEQ ID NO:39, SEQ ID NO:41, SEQ ID NO:43, SEQ ID NO:45, SEQ ID
NO:47, SEQ ID NO:49, SEQ ID NO:51, SEQ ID NO:53, SEQ ID NO:55, SEQ
ID NO:57, SEQ ID NO:59, SEQ ID NO:61, SEQ ID NO:63, SEQ ID NO:65,
20 SEQ ID NO:67, SEQ ID NO:69, SEQ ID NO:71, SEQ ID NO:73, SEQ ID
NO:75, SEQ ID NO:77, SEQ ID NO:79, SEQ ID NO:81, SEQ ID NO:83, SEQ
ID NO:85, SEQ ID NO:87, SEQ ID NO:89, SEQ ID NO:91, SEQ ID NO:93,
SEQ ID NO:95, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID
NO:103, SEQ ID NO:105, and SEQ ID NO:107;
25

(b) a nucleic acid sequence encoding a polypeptide selected from the group
consisting of: a nucleic acid sequence encoding a polypeptide selected from the
group consisting of: SEQ ID NO:3, SEQ ID NO:5, SEQ ID NO:7, SEQ ID
NO:9, SEQ ID NO:11, SEQ ID NO:13, SEQ ID NO:15, SEQ ID NO:17, SEQ ID
NO:19, SEQ ID NO:21, SEQ ID NO:23, SEQ ID NO:25, SEQ ID NO:27, SEQ
30

- 5 ID NO:29, SEQ ID NO:31, SEQ ID NO:33, SEQ ID NO:35, SEQ ID NO:37, SEQ ID NO:39, SEQ ID NO:41, SEQ ID NO:43, SEQ ID NO:45, SEQ ID NO:47, SEQ ID NO:49, SEQ ID NO:51, SEQ ID NO:53, SEQ ID NO:55, SEQ ID NO:57, SEQ ID NO:59, SEQ ID NO:61, SEQ ID NO:63, SEQ ID NO:65, SEQ ID NO:67, SEQ ID NO:69, SEQ ID NO:71, SEQ ID NO:73, SEQ ID NO:75, SEQ ID NO:77, SEQ ID NO:79, SEQ ID NO:81, SEQ ID NO:83, SEQ ID NO:85, SEQ ID NO:87, SEQ ID NO:89, SEQ ID NO:91, SEQ ID NO:93, SEQ ID NO:95, SEQ ID NO:97, SEQ ID NO:99, SEQ ID NO:101, SEQ ID NO:103, SEQ ID NO:105, and SEQ ID NO:107, lacking its associated signal peptide;
- 10
- (c) the sequence of SEQ ID NO:1, wherein said nucleic acid encodes a polypeptide that infects *B. anthracis*;
- (d) a polynucleotide with at least 60% identity to the polynucleotide sequence of SEQ ID NO:1, wherein said nucleic acid encodes a polypeptide that infects *B. anthracis*; or
- 15
- (e) a polynucleotide of SEQ ID NO:1, with up to 50 conservative nucleotide substitutions wherein said nucleic acid encodes a polypeptide that infects *B. anthracis*.
17. The isolated nucleic acid of claim 16, wherein the hybridization occurs under high stringency conditions selected from the group consisting of:
- 20
- (a) 0.015 M sodium chloride/0.0015 M sodium citrate/0.1% sodium dodecyl sulfate at 50°C;
- (b) 50% (v/v) formamide with 0.1% bovine serum albumin/0.1% Ficoll/0.1% polyvinylpyrrolidone/50mM sodium phosphate buffer at pH 6.5 with 750 mM sodium chloride, 75 mM sodium citrate at 42°C; and
- 25
- (c) 50% formamide, 5 x SSC (0.75 M sodium chloride, 0.075 M sodium citrate), 50 mM sodium phosphate (pH 6.8), 0.1% sodium pyrophosphate, 5 x Denhardt's solution, sonicated salmon sperm DNA (50 µg/ml), 0.1% sodium dodecyl sulphate, and 10% dextran sulfate at 42°C, with washes at 42°C in 0.2 x SSC

(0.75 M sodium chloride, 0.075 M sodium citrate) and 50% formamide at 55°C, followed by a high-stringency wash consisting of 0.1 x SSC (0.75 M sodium chloride, 0.075 N sodium citrate) containing EDTA at 55°C.

18. An isolated nucleic acid that hybridizes under high stringency conditions to a
5 hybridization probe, the nucleotide sequence of which consists essentially of an open reading frame from SEQ ID NO:1, or the complement of SEQ ID NO:1.
19. An isolated nucleic acid that hybridizes under high stringency conditions to a hybridization probe, the nucleotide sequence of which consists essentially of the polynucleotide sequence of SEQ ID NO:110, SEQ ID NO:111, SEQ ID NO:112,
10 SEQ ID NO:113, or the complement of thereof.
20. An isolated nucleic acid that hybridizes under high stringency conditions to a hybridization probe, the nucleotide sequence of which consists essentially of the polynucleotide sequence of SEQ ID NO:111, or the complement of SEQ ID NO:111.
- 15 21. A vector comprising the nucleic acid of claim 1.
22. A vector comprising the nucleic acid of claim 15.
23. A vector comprising the nucleic acid of claim 16.
24. An expression vector comprising the nucleic acid sequence of claim 1 operably associated with a promoter.
- 20 25. An expression vector comprising the nucleic acid sequence of claim 15 operably associated with a promoter.
26. An expression vector comprising the nucleic acid sequence of claim 16 operably associated with a promoter.
27. A host cell comprising the vector of claim 21.
- 25 28. A host cell comprising the vector of claim 22.
29. A host cell comprising the vector of claim 23.
30. A host cell comprising the vector of claim 24.

31. A host cell comprising the vector of claim 25.

32. A host cell comprising the vector of claim 26.

33. A method of screening for a compound that binds to a polypeptide, the method comprising:

- 5 (a) providing the nucleic acid of an open reading frame from SEQ ID NO:1;
- (b) introducing the nucleic acid into a cell and allowing the cell to produce the polypeptide encoded by the nucleic acid;
- (c) contacting a test compound with the polypeptide; and
- 10 (d) determining whether the test compound has bound to the polypeptide.

1. An isolated polynucleotide selected from the group consisting of:
 - (a) a polynucleotide with at least 60% identity to the polynucleotide sequence of ORF 14 from SEQ ID NO:1; and
 - 5 (b) a polynucleotide of ORF 14 from SEQ ID NO:1, with up to 30 conservative nucleotide substitutions;wherein the isolated polynucleotide encodes a polypeptide that binds to the surface of *B. anthracis*.
- 10 2. An isolated nucleic acid consisting of the sequence of ORF 14 from SEQ ID NO:1.
3. A DNA construct comprising an isolated nucleic acid molecule comprising the nucleotide sequence of ORF 14 from SEQ ID NO:1 operatively linked to a regulatory sequence.
- 15 4. An isolated nucleic acid molecule comprising at least 100 contiguous nucleotides of ORF 14 from SEQ ID NO:1, that encodes a polypeptide that binds to the surface of *B. anthracis*.
5. An isolated nucleic acid encoding a polypeptide which binds to the surface of *B. anthracis*, and having at least 60% nucleic acid sequence identity to:
 - (a) a nucleic acid sequence encoding the polypeptide of SEQ ID NO:29; or
 - 20 (b) a nucleic acid sequence encoding the polypeptide of SEQ ID NO:29, lacking its associated signal peptide.
6. An isolated nucleic acid encoding a polypeptide comprising an amino acid sequence at least 60% identical to a polypeptide sequence of SEQ ID NO:29, wherein the polypeptide that binds to the surface of *B. anthracis*.
- 25 7. An isolated nucleic acid encoding a polypeptide comprising the amino acid sequence set forth in SEQ ID NO:29, with up to 30 conservative amino acid substitutions, wherein the polypeptide binds to the surface of *B. anthracis*.

8. An isolated nucleic acid that hybridizes under high stringency conditions to the coding sequence of SEQ ID NO:29, wherein said nucleic acid encodes a polypeptide that binds to the surface of *B. anthracis*.
9. An isolated nucleic acid that hybridizes under high stringency conditions to:
- 5 (a) a nucleic acid sequence encoding the polypeptide of SEQ ID NO:29;
- (b) a nucleic acid sequence encoding the polypeptide shown in SEQ ID NO:29, lacking its associated signal peptide;
- (c) a nucleic acid sequence of the ORF 14 portion of SEQ ID NO:1, wherein said nucleic acid encodes a polypeptide that binds to the surface of *B.*
- 10 *anthracis*.
10. The isolated nucleic acid of claim 9, wherein the hybridization occurs under high stringency conditions selected from the group consisting of:
- (a) 0.015 M sodium chloride/0.0015 M sodium citrate/0.1% sodium dodecyl sulfate at 50°C;
- 15 (b) 50% (v/v) formamide with 0.1% bovine serum albumin/0.1% Ficoll/0.1% polyvinylpyrrolidone/50mM sodium phosphate buffer at pH 6.5 with 750 mM sodium chloride, 75 mM sodium citrate at 42°C; and
- (c) 50% formamide, 5 x SSC (0.75 M sodium chloride, 0.075 M sodium citrate), 50 mM sodium phosphate (pH 6.8), 0.1% sodium pyrophosphate, 5
- 20 x Denhardt's solution, sonicated salmon sperm DNA (50 µg/ml), 0.1% sodium dodecyl sulphate, and 10% dextran sulfate at 42°C, with washes at 42°C in 0.2 x SSC (0.75 M sodium chloride, 0.075 M sodium citrate) and 50% formamide at 55°C, followed by a high-stringency wash consisting of 0.1 x SSC (0.75 M sodium chloride, 0.075 N sodium citrate) containing
- 25 EDTA at 55°C.
11. An isolated nucleic acid that hybridizes under high stringency conditions to a hybridization probe the nucleotide sequence of which consists essentially of an ORF 14 from SEQ ID NO:1, or the complement thereof.

12. A vector comprising the nucleic acid of claim 1.
13. A vector comprising the nucleic acid of claim 5.
14. An expression vector comprising the nucleic acid sequence of the ORF 14 portion of SEQ ID NO:1, operably associated with a promoter.
- 5 15. A host cell comprising the vector of claim 12.
16. A host cell comprising the vector of claim 13.
17. A method of screening for a compound that binds to a polypeptide, the method comprising:
- (a) providing the nucleic acid of ORF 14 from SEQ ID NO:1;
 - 10 (b) introducing the nucleic acid into a cell and allowing the cell to produce the polypeptide encoded by the nucleic acid;
 - (c) contacting a test compound with the polypeptide; and
 - (d) determining whether the test compound has bound to the polypeptide.
- 15 18. An isolated polypeptide having at least 80% amino acid sequence identity to:
- (a) the amino acid sequence of the polypeptide shown in SEQ ID NO:29; or
 - (b) the amino acid sequence of the polypeptide shown in SEQ ID NO:29, lacking its associated signal peptide;
- wherein the polypeptide is able to bind to the surface of *B. anthracis*.
- 20 19. An isolated polypeptide comprising:
- (a) the amino acid sequence of the polypeptide shown in SEQ ID NO:29; or
 - (b) the amino acid sequence of the polypeptide shown in SEQ ID NO:29, lacking its associated signal peptide.
- 25 20. A purified polypeptide, the amino acid sequence of which consists of a polypeptide sequence of SEQ ID NO:29.

21. A purified polypeptide, the amino acid sequence of which is encoded by the ORF 14 from SEQ ID NO:1.

22. A method for preparing a polypeptide, the method comprising the step of culturing the host cell of claim 15 under conditions that permit expression of the polypeptide from the expression vector, and isolating the polypeptide from the host cell.

23. A method for preparing a polypeptide, the method comprising the step of culturing the host cell of claim 16 under conditions that permit expression of the polypeptide from the expression vector, and isolating the polypeptide from the host cell.

24. A fusion polypeptide comprising a polypeptide of claim 18 fused to a heterologous polypeptide.

25. A fusion polypeptide comprising a polypeptide of claim 19 fused to a heterologous polypeptide.

1. An isolated polynucleotide selected from the group consisting of:
 - (a) a polynucleotide with at least 60% identity to the polynucleotide sequence of ORF 17 of SEQ ID NO:1; and
 - (b) a polynucleotide of ORF 17 of SEQ ID NO:1, with up to 30 conservative nucleotide substitutions;wherein the isolated polynucleotide encodes a polypeptide that kills *B. anthracis*.
2. An isolated nucleic acid consisting of the sequence of ORF 17 from SEQ ID NO:1.
3. A DNA construct comprising an isolated nucleic acid molecule comprising the nucleotide sequence of ORF 17 from SEQ ID NO:1 operatively linked to a regulatory sequence.
4. An isolated nucleic acid molecule comprising at least 100 contiguous nucleotides of ORF 17 from SEQ ID NO:1, that encodes a polypeptide that kills *B. anthracis*.
5. An isolated nucleic acid encoding a polypeptide which kills *B. anthracis*, and having at least 60% nucleic acid sequence identity to:
 - (a) a nucleic acid sequence encoding the polypeptide of SEQ ID NO:35; or
 - (b) a nucleic acid sequence encoding the polypeptide of SEQ ID NO:35, lacking its associated signal peptide;
6. An isolated nucleic acid encoding a polypeptide comprising an amino acid sequence at least 60% identical to a polypeptide sequence of SEQ ID NO:35, wherein the polypeptide kills *B. anthracis*.
7. An isolated nucleic acid encoding a polypeptide comprising the amino acid sequence set forth in SEQ ID NO:35, with up to 30 conservative amino acid substitutions, wherein the polypeptide kills *B. anthracis*.

8. An isolated nucleic acid that hybridizes under high stringency conditions to the coding sequence of SEQ ID NO:35, wherein said nucleic acid encodes a polypeptide that kills *B. anthracis*.
9. An isolated nucleic acid that hybridizes under high stringency conditions to:
- 5 (a) a nucleic acid sequence encoding the polypeptide of SEQ ID NO:35;
- (b) a nucleic acid sequence encoding the polypeptide shown in SEQ ID NO:35, lacking its associated signal peptide;
- (c) a nucleic acid sequence of the ORF 17 portion of SEQ ID NO:1, wherein said nucleic acid encodes a polypeptide that kills *B. anthracis*.
- 10 The isolated nucleic acid of claim 9, wherein the hybridization occurs under high stringency conditions selected from the group consisting of:
- (a) 0.015 M sodium chloride/0.0015 M sodium citrate/0.1% sodium dodecyl sulfate at 50°C;
- (b) 50% (v/v) formamide with 0.1% bovine serum albumin/0.1% Ficoll/0.1% polyvinylpyrrolidone/50mM sodium phosphate buffer at pH 6.5 with 750 mM sodium chloride, 75 mM sodium citrate at 42°C; and
- 15 (c) 50% formamide, 5 x SSC (0.75 M sodium chloride, 0.075 M sodium citrate), 50 mM sodium phosphate (pH 6.8), 0.1% sodium pyrophosphate, 5 x Denhardt's solution, sonicated salmon sperm DNA (50 µg/ml), 0.1% sodium dodecyl sulphate, and 10% dextran sulfate at 42°C, with washes at 42°C in 0.2 x SSC (0.75 M sodium chloride, 0.075 M sodium citrate) and 50% formamide at 55°C, followed by a high-stringency wash consisting of 0.1 x SSC (0.75 M sodium chloride, 0.075 N sodium citrate) containing EDTA at 55°C.
- 20 11. An isolated nucleic acid that hybridizes under high stringency conditions to a hybridization probe the nucleotide sequence of which consists essentially of an ORF 17 from SEQ ID NO:1, or the complement of thereof.
- 25 12. A vector comprising the nucleic acid of claim 1.

13. A vector comprising the nucleic acid of claim 5.
14. An expression vector comprising the nucleic acid sequence of the ORF 17 portion of SEQ ID NO:1, operably associated with a promoter.
15. A host cell comprising the vector of claim 12.
- 5 16. A host cell comprising the vector of claim 13.
17. A method of screening for a compound that binds to a polypeptide, the method comprising:
- (a) providing the nucleic acid of ORF 17 from SEQ ID NO:1;
 - (b) introducing the nucleic acid into a cell and allowing the cell to produce the polypeptide encoded by the nucleic acid;
 - 10 (c) contacting a test compound with the polypeptide; and
 - (d) determining whether the test compound has bound to the polypeptide.
18. An isolated polypeptide having at least 80% amino acid sequence identity to:
- 15 (a) the amino acid sequence of the polypeptide shown in SEQ ID NO:35; or
 - (b) the amino acid sequence of the polypeptide shown in SEQ ID NO:35, lacking its associated signal peptide;
- wherein the polypeptide kills *B. anthracis*.
19. An isolated polypeptide comprising:
- 20 (a) the amino acid sequence of the polypeptide shown in SEQ ID NO:35; or
 - (b) the amino acid sequence of the polypeptide shown in SEQ ID NO:35, lacking its associated signal peptide.
20. A purified polypeptide, the amino acid sequence of which consists of a polypeptide sequence of SEQ ID NO:35.
- 25 21. A purified polypeptide, the amino acid sequence of which is encoded by an ORF 17 from SEQ ID NO:1.

22. A method for preparing a polypeptide, the method comprising the step of culturing the host cell of claim 15 under conditions that permit expression of the polypeptide from the expression vector, and isolating the polypeptide from the host cell.
- 5 23. A method for preparing a polypeptide, the method comprising the step of culturing the host cell of claim 16 under conditions that permit expression of the polypeptide from the expression vector, and isolating the polypeptide from the host cell.
- 10 24. A fusion polypeptide comprising a polypeptide of claim 18 fused to a heterologous polypeptide.
25. A fusion polypeptide comprising a polypeptide of claim 19 fused to a heterologous polypeptide.

1. An isolated polynucleotide selected from the group consisting of:
 - (a) a polynucleotide with at least 60% identity to the polynucleotide sequence of ORF 41 of SEQ ID NO:1; and
 - 5 (b) a polynucleotide of ORF 41 of SEQ ID NO:1, with up to 30 conservative nucleotide substitutions;wherein the isolated polynucleotide encodes a polypeptide that exhibits Fosfomycin resistance.
- 10 2. An isolated nucleic acid consisting of the sequence of ORF 41 from SEQ ID NO:1.
3. A DNA construct comprising an isolated nucleic acid molecule comprising the nucleotide sequence of ORF 41 from SEQ ID NO:1 operatively linked to a regulatory sequence.
- 15 4. An isolated nucleic acid molecule comprising at least 100 contiguous nucleotides of ORF 41 from SEQ ID NO:1, that encodes a polypeptide that exhibits Fosfomycin resistance.
5. An isolated nucleic acid encoding a polypeptide which exhibits Fosfomycin resistance, and having at least 60% nucleic acid sequence identity to:
 - (a) a nucleic acid sequence encoding the polypeptide of SEQ ID NO:83; or
 - 20 (b) a nucleic acid sequence encoding the polypeptide of SEQ ID NO:83, lacking its associated signal peptide;
6. An isolated nucleic acid encoding a polypeptide comprising an amino acid sequence at least 60% identical to a polypeptide sequence of SEQ ID NO:83, wherein the polypeptide exhibits Fosfomycin resistance.
- 25 7. An isolated nucleic acid encoding a polypeptide comprising the amino acid sequence set forth in SEQ ID NO:83, with up to 30 conservative amino acid substitutions, wherein the polypeptide exhibits Fosfomycin resistance.

8. An isolated nucleic acid that hybridizes under high stringency conditions to the coding sequence of SEQ ID NO:83, wherein said nucleic acid encodes a polypeptide that exhibits Fosfomycin resistance.
9. An isolated nucleic acid that hybridizes under high stringency conditions to:
- 5 (a) a nucleic acid sequence encoding the polypeptide of SEQ ID NO:83;
- (b) a nucleic acid sequence encoding the polypeptide shown in SEQ ID NO:83, lacking its associated signal peptide;
- (c) a nucleic acid sequence of the ORF 41 portion of SEQ ID NO:1, wherein said nucleic acid encodes a polypeptide that exhibits Fosfomycin
- 10 resistance.
10. The isolated nucleic acid of claim 9, wherein the hybridization occurs under high stringency conditions selected from the group consisting of:
- (a) 0.015 M sodium chloride/0.0015 M sodium citrate/0.1% sodium dodecyl sulfate at 50°C;
- 15 (b) 50% (v/v) formamide with 0.1% bovine serum albumin/0.1% Ficoll/0.1% polyvinylpyrrolidone/50mM sodium phosphate buffer at pH 6.5 with 750 mM sodium chloride, 75 mM sodium citrate at 42°C; and
- (c) 50% formamide, 5 x SSC (0.75 M sodium chloride, 0.075 M sodium citrate), 50 mM sodium phosphate (pH 6.8), 0.1% sodium pyrophosphate, 5
- 20 x Denhardt's solution, sonicated salmon sperm DNA (50 µg/ml), 0.1% sodium dodecyl sulphate, and 10% dextran sulfate at 42°C, with washes at 42°C in 0.2 x SSC (0.75 M sodium chloride, 0.075 M sodium citrate) and 50% formamide at 55°C, followed by a high-stringency wash consisting of 0.1 x SSC (0.75 M sodium chloride, 0.075 N sodium citrate) containing
- 25 EDTA at 55°C.
11. An isolated nucleic acid that hybridizes under high stringency conditions to a hybridization probe the nucleotide sequence of which consists essentially of an ORF 41 from SEQ ID NO:1, or the complement of thereof.

12. A vector comprising the nucleic acid of claim 1.
13. A vector comprising the nucleic acid of claim 5.
14. An expression vector comprising the nucleic acid sequence of the ORF 41 portion of SEQ ID NO:1, operably associated with a promoter.
- 5 15. A host cell comprising the vector of claim 12.
16. A host cell comprising the vector of claim 13.
17. A method of screening for a compound that binds to a polypeptide, the method comprising:
- (a) providing the nucleic acid of ORF 41 from SEQ ID NO:1;
 - 10 (b) introducing the nucleic acid into a cell and allowing the cell to produce the polypeptide encoded by the nucleic acid;
 - (c) contacting a test compound with the polypeptide; and
 - (d) determining whether the test compound has bound to the polypeptide.
- 15 18. An isolated polypeptide having at least 80% amino acid sequence identity to:
- (a) the amino acid sequence of the polypeptide shown in SEQ ID NO:83; or
 - (b) the amino acid sequence of the polypeptide shown in SEQ ID NO:83, lacking its associated signal peptide;
- wherein the polypeptide exhibits Fosfomycin resistance.
- 20 19. An isolated polypeptide comprising:
- (a) the amino acid sequence of the polypeptide shown in SEQ ID NO:83; or
 - (b) the amino acid sequence of the polypeptide shown in SEQ ID NO:83, lacking its associated signal peptide.
- 25 20. A purified polypeptide, the amino acid sequence of which consists of a polypeptide sequence of SEQ ID NO:35.

21. A purified polypeptide, the amino acid sequence of which is encoded by an ORF 41 from SEQ ID NO:1.

22. A method for preparing a polypeptide, the method comprising the step of culturing the host cell of claim 15 under conditions that permit expression of the polypeptide from the expression vector, and isolating the polypeptide from the host cell.

23. A method for preparing a polypeptide, the method comprising the step of culturing the host cell of claim 16 under conditions that permit expression of the polypeptide from the expression vector, and isolating the polypeptide from the host cell.

24. A fusion polypeptide comprising a polypeptide of claim 18 fused to a heterologous polypeptide.

25. A fusion polypeptide comprising a polypeptide of claim 19 fused to a heterologous polypeptide.

1. An isolated polynucleotide selected from the group consisting of:
 - (a) a polynucleotide of SEQ ID NO:2,
 - (b) a polynucleotide with at least 60% identity to the polynucleotide sequence of SEQ ID NO:2, and
 - (c) a polynucleotide of SEQ ID NO:2, with up to 50 conservative nucleotide substitutions;wherein the isolated polynucleotide encodes a polypeptide that infects *B. anthracis*.
2. An isolated polynucleotide having at least 70% identity to the polynucleotide sequence of SEQ ID NO:2.
3. The isolated polynucleotide of claim 2, wherein the isolated polynucleotide has at least 80% identity to the polynucleotide sequence of SEQ ID NO:2.
4. The isolated polynucleotide of claim 2, wherein the isolated polynucleotide has at least 90% identity to the polynucleotide sequence of SEQ ID NO:2.
5. The isolated polynucleotide of claim 1, wherein the isolated polynucleotide encodes a polypeptide that specifically binds to *B. anthracis* and RSVF1.
6. The isolated polynucleotide of claim 1, wherein the isolated polynucleotide encodes a polypeptide that specifically binds to *B. anthracis* and RSVF1 at a level of 100 PFU/ml or greater, but binds to other *B. cereus* bacteria at a level of less than 100 PFU/ml.
7. An isolated nucleic acid comprising an open reading frame of SEQ ID NO:2.
8. An isolated nucleic acid consisting of the sequence of SEQ ID NO:2.
9. An isolated nucleic acid comprising the coding sequence of SEQ ID NO:2.
10. A DNA construct comprising an isolated nucleic acid molecule comprising the nucleotide sequence of an open reading frame of SEQ ID NO:2, operatively linked to a regulatory sequence.

11. An isolated nucleic acid molecule comprising at least 50 contiguous nucleotides of SEQ ID NO:2.
12. An isolated nucleic acid molecule comprising the contiguous nucleotides of an open reading frame from SEQ ID NO:2, with up to 50 conservative nucleic acid substitutions.
13. An isolated nucleic acid that hybridizes under high stringency conditions to the coding sequence of SEQ ID NO:2, wherein said nucleic acid encodes a polypeptide that infects *B. anthracis*.
14. The isolated nucleic acid of claim 12, wherein the nucleic acid is at least 15 nucleotides in length.
15. An isolated nucleic acid selected from the group consisting of:
16. a nucleic acid sequence encoding a polypeptide selected from the group consisting of: SEQ ID NO:4, SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10, SEQ ID NO:12, SEQ ID NO:14, SEQ ID NO:16, SEQ ID NO:18, SEQ ID NO:20, SEQ ID NO:22, SEQ ID NO:24, SEQ ID NO:26, SEQ ID NO:28, SEQ ID NO:30, SEQ ID NO:32, SEQ ID NO:34, SEQ ID NO:36, SEQ ID NO:38, SEQ ID NO:40, SEQ ID NO:42, SEQ ID NO:44, SEQ ID NO:46, SEQ ID NO:48, SEQ ID NO:50, SEQ ID NO:52, SEQ ID NO:54, SEQ ID NO:56, SEQ ID NO:58, SEQ ID NO:60, SEQ ID NO:62, SEQ ID NO:64, SEQ ID NO:66, SEQ ID NO:68, SEQ ID NO:70, SEQ ID NO:72, SEQ ID NO:74, SEQ ID NO:76, SEQ ID NO:78, SEQ ID NO:80, SEQ ID NO:82, SEQ ID NO:84, SEQ ID NO:86, SEQ ID NO:88, SEQ ID NO:90, SEQ ID NO:92, SEQ ID NO:94, SEQ ID NO:96, SEQ ID NO:98, SEQ ID NO:100, SEQ ID NO:102, SEQ ID NO:104, SEQ ID NO:106, SEQ ID NO:108, and SEQ ID NO:109; and
- (a) a nucleic acid sequence encoding a polypeptide selected from the group consisting of: SEQ ID NO:4, SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10, SEQ ID NO:12, SEQ ID NO:14, SEQ ID NO:16, SEQ ID NO:18, SEQ ID NO:20, SEQ ID NO:22, SEQ ID NO:24, SEQ ID NO:26, SEQ ID NO:28, SEQ ID NO:30, SEQ ID NO:32, SEQ ID NO:34, SEQ ID NO:36,

SEQ ID NO:38, SEQ ID NO:40, SEQ ID NO:42, SEQ ID NO:44, SEQ ID NO:46, SEQ ID NO:48, SEQ ID NO:50, SEQ ID NO:52, SEQ ID NO:54, SEQ ID NO:56, SEQ ID NO:58, SEQ ID NO:60, SEQ ID NO:62, SEQ ID NO:64, SEQ ID NO:66, SEQ ID NO:68, SEQ ID NO:70, SEQ ID NO:72, SEQ ID NO:74, SEQ ID NO:76, SEQ ID NO:78, SEQ ID NO:80, SEQ ID NO:82, SEQ ID NO:84, SEQ ID NO:86, SEQ ID NO:88, SEQ ID NO:90, SEQ ID NO:92, SEQ ID NO:94, SEQ ID NO:96, SEQ ID NO:98, SEQ ID NO:100, SEQ ID NO:102, SEQ ID NO:104, SEQ ID NO:106, SEQ ID NO:108, and SEQ ID NO:109, lacking its associated signal peptide.

17. An isolated nucleic acid that hybridizes under high stringency conditions to:

(a) a nucleic acid sequence encoding a polypeptide selected from the group consisting of: SEQ ID NO:4, SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10, SEQ ID NO:12, SEQ ID NO:14, SEQ ID NO:16, SEQ ID NO:18, SEQ ID NO:20, SEQ ID NO:22, SEQ ID NO:24, SEQ ID NO:26, SEQ ID NO:28, SEQ ID NO:30, SEQ ID NO:32, SEQ ID NO:34, SEQ ID NO:36, SEQ ID NO:38, SEQ ID NO:40, SEQ ID NO:42, SEQ ID NO:44, SEQ ID NO:46, SEQ ID NO:48, SEQ ID NO:50, SEQ ID NO:52, SEQ ID NO:54, SEQ ID NO:56, SEQ ID NO:58, SEQ ID NO:60, SEQ ID NO:62, SEQ ID NO:64, SEQ ID NO:66, SEQ ID NO:68, SEQ ID NO:70, SEQ ID NO:72, SEQ ID NO:74, SEQ ID NO:76, SEQ ID NO:78, SEQ ID NO:80, SEQ ID NO:82, SEQ ID NO:84, SEQ ID NO:86, SEQ ID NO:88, SEQ ID NO:90, SEQ ID NO:92, SEQ ID NO:94, SEQ ID NO:96, SEQ ID NO:98, SEQ ID NO:100, SEQ ID NO:102, SEQ ID NO:104, SEQ ID NO:106, SEQ ID NO:108, and SEQ ID NO:109;

(b) a nucleic acid sequence encoding a polypeptide selected from the group consisting of: SEQ ID NO:4, SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:10, SEQ ID NO:12, SEQ ID NO:14, SEQ ID NO:16, SEQ ID NO:18, SEQ ID NO:20, SEQ ID NO:22, SEQ ID NO:24, SEQ ID NO:26, SEQ ID NO:28, SEQ ID NO:30, SEQ ID NO:32, SEQ ID NO:34, SEQ ID NO:36, SEQ ID NO:38, SEQ ID NO:40, SEQ ID NO:42, SEQ ID NO:44, SEQ ID

NO:46, SEQ ID NO:48, SEQ ID NO:50, SEQ ID NO:52, SEQ ID NO:54, SEQ ID NO:56, SEQ ID NO:58, SEQ ID NO:60, SEQ ID NO:62, SEQ ID NO:64, SEQ ID NO:66, SEQ ID NO:68, SEQ ID NO:70, SEQ ID NO:72, SEQ ID NO:74, SEQ ID NO:76, SEQ ID NO:78, SEQ ID NO:80, SEQ ID NO:82, SEQ ID NO:84, SEQ ID NO:86, SEQ ID NO:88, SEQ ID NO:90, SEQ ID NO:92, SEQ ID NO:94, SEQ ID NO:96, SEQ ID NO:98, SEQ ID NO:100, SEQ ID NO:102, SEQ ID NO:104, SEQ ID NO:106, SEQ ID NO:108, and SEQ ID NO:109, lacking its associated signal peptide;

(c) the sequence of SEQ ID NO:2, wherein said nucleic acid encodes a polypeptide that infects *B. anthracis*;

(d) a polynucleotide with at least 60% identity to the polynucleotide sequence of SEQ ID NO:2, wherein said nucleic acid encodes a polypeptide that infects *B. anthracis*; or

(e) a polynucleotide of SEQ ID NO:2, with up to 50 conservative nucleotide substitutions wherein said nucleic acid encodes a polypeptide that infects *B. anthracis*.

18. The isolated nucleic acid of claim 16, wherein the hybridization occurs under high stringency conditions selected from the group consisting of:

(a) 0.015 M sodium chloride/0.0015 M sodium citrate/0.1% sodium dodecyl sulfate at 50°C;

(b) 50% (v/v) formamide with 0.1% bovine serum albumin/0.1% Ficoll/0.1% polyvinylpyrrolidone/50mM sodium phosphate buffer at pH 6.5 with 750 mM sodium chloride, 75 mM sodium citrate at 42°C; and

(c) 50% formamide, 5 x SSC (0.75 M sodium chloride, 0.075 M sodium citrate), 50 mM sodium phosphate (pH 6.8), 0.1% sodium pyrophosphate, 5 x Denhardt's solution, sonicated salmon sperm DNA (50 µg/ml), 0.1% sodium dodecyl sulphate, and 10% dextran sulfate at 42°C, with washes at 42°C in 0.2 x SSC (0.75 M sodium chloride, 0.075 M sodium citrate) and 50% formamide at 55°C, followed by a high-stringency wash consisting of

0.1 x SSC (0.75 M sodium chloride, 0.075 N sodium citrate) containing EDTA at 55°C.

- 5 19. An isolated nucleic acid that hybridizes under high stringency conditions to a hybridization probe, the nucleotide sequence of which consists essentially of an open reading frame from SEQ ID NO:2, or the complement of SEQ ID NO:2.
20. A vector comprising the nucleic acid of claim 1.
21. A vector comprising the nucleic acid of claim 15.
22. A vector comprising the nucleic acid of claim 16.
- 10 23. An expression vector comprising the nucleic acid sequence of claim 1 operably associated with a promoter.
24. An expression vector comprising the nucleic acid sequence of claim 15 operably associated with a promoter.
- 15 25. An expression vector comprising the nucleic acid sequence of claim 16 operably associated with a promoter.
26. A host cell comprising the vector of claim 21.
27. A host cell comprising the vector of claim 22.
28. A host cell comprising the vector of claim 23.
29. A host cell comprising the vector of claim 24.
- 20 30. A host cell comprising the vector of claim 25.
31. A host cell comprising the vector of claim 26.
32. A method of screening for a compound that binds to a polypeptide, the method comprising:
- 25 (a) providing the nucleic acid of an open reading frame from SEQ ID NO:2;

- (b) introducing the nucleic acid into a cell and allowing the cell to produce the polypeptide encoded by the nucleic acid;
- (c) contacting a test compound with the polypeptide; and
- (d) determining whether the test compound has bound to the polypeptide.

1. An isolated polynucleotide selected from the group consisting of:
 - (a) a polynucleotide with at least 60% identity to the polynucleotide sequence of ORF 14 from SEQ ID NO:2; and
 - (b) a polynucleotide of ORF 14 from SEQ ID NO:2, with up to 30 conservative nucleotide substitutions;wherein the isolated polynucleotide encodes a polypeptide that binds to the surface of *B. anthracis*.
2. An isolated nucleic acid consisting of the sequence of ORF 14 from SEQ ID NO:2.
3. A DNA construct comprising an isolated nucleic acid molecule comprising the nucleotide sequence of ORF 14 from SEQ ID NO:2 operatively linked to a regulatory sequence.
4. An isolated nucleic acid molecule comprising at least 100 contiguous nucleotides of ORF 14 from SEQ ID NO:2, that encodes a polypeptide that binds to the surface of *B. anthracis*.
5. An isolated nucleic acid encoding a polypeptide which binds to the surface of *B. anthracis*, and having at least 60% nucleic acid sequence identity to:
 - (a) a nucleic acid sequence encoding the polypeptide of SEQ ID NO:30; or
 - (b) a nucleic acid sequence encoding the polypeptide of SEQ ID NO:30, lacking its associated signal peptide.
6. An isolated nucleic acid encoding a polypeptide comprising an amino acid sequence at least 60% identical to a polypeptide sequence of SEQ ID NO:30, wherein the polypeptide that binds to the surface of *B. anthracis*.
7. An isolated nucleic acid encoding a polypeptide comprising the amino acid sequence set forth in SEQ ID NO:30, with up to 30 conservative amino acid substitutions, wherein the polypeptide binds to the surface of *B. anthracis*.

8. An isolated nucleic acid that hybridizes under high stringency conditions to the coding sequence of SEQ ID NO:30, wherein said nucleic acid encodes a polypeptide that binds to the surface of *B. anthracis*.
9. An isolated nucleic acid that hybridizes under high stringency conditions to:
- 5 (a) a nucleic acid sequence encoding the polypeptide of SEQ ID NO:30;
- (b) a nucleic acid sequence encoding the polypeptide shown in SEQ ID NO:30, lacking its associated signal peptide;
- (c) a nucleic acid sequence of the ORF 14 portion of SEQ ID NO:2, wherein said nucleic acid encodes a polypeptide that binds to the surface of *B.*
- 10 *anthracis*.
10. The isolated nucleic acid of claim 9, wherein the hybridization occurs under high stringency conditions selected from the group consisting of:
- (a) 0.015 M sodium chloride/0.0015 M sodium citrate/0.1% sodium dodecyl sulfate at 50°C;
- 15 (b) 50% (v/v) formamide with 0.1% bovine serum albumin/0.1% Ficoll/0.1% polyvinylpyrrolidone/50mM sodium phosphate buffer at pH 6.5 with 750 mM sodium chloride, 75 mM sodium citrate at 42°C; and
- (c) 50% formamide, 5 x SSC (0.75 M sodium chloride, 0.075 M sodium citrate), 50 mM sodium phosphate (pH 6.8), 0.1% sodium pyrophosphate, 5
- 20 x Denhardt's solution, sonicated salmon sperm DNA (50 µg/ml), 0.1% sodium dodecyl sulphate, and 10% dextran sulfate at 42°C, with washes at 42°C in 0.2 x SSC (0.75 M sodium chloride, 0.075 M sodium citrate) and 50% formamide at 55°C, followed by a high-stringency wash consisting of 0.1 x SSC (0.75 M sodium chloride, 0.075 N sodium citrate) containing
- 25 EDTA at 55°C.
11. An isolated nucleic acid that hybridizes under high stringency conditions to a hybridization probe the nucleotide sequence of which consists essentially of an ORF 14 from SEQ ID NO:2, or the complement thereof.

12. A vector comprising the nucleic acid of claim 1.
13. A vector comprising the nucleic acid of claim 5.
14. An expression vector comprising the nucleic acid sequence of the ORF 14 portion of SEQ ID NO:2, operably associated with a promoter.
- 5 15. A host cell comprising the vector of claim 12.
16. A host cell comprising the vector of claim 13.
17. A method of screening for a compound that binds to a polypeptide, the method comprising:
- 10 (a) providing the nucleic acid of ORF 14 from SEQ ID NO:2;
- (b) introducing the nucleic acid into a cell and allowing the cell to produce the polypeptide encoded by the nucleic acid;
- (c) contacting a test compound with the polypeptide; and
- (d) determining whether the test compound has bound to the polypeptide.
- 15 18. An isolated polypeptide having at least 80% amino acid sequence identity to:
- (a) the amino acid sequence of the polypeptide shown in SEQ ID NO:30; or
- (b) the amino acid sequence of the polypeptide shown in SEQ ID NO:30, lacking its associated signal peptide;
- wherein the polypeptide is able to bind to the surface of *B. anthracis*.
- 20 19. An isolated polypeptide comprising:
- (a) the amino acid sequence of the polypeptide shown in SEQ ID NO:30; or
- (b) the amino acid sequence of the polypeptide shown in SEQ ID NO:30, lacking its associated signal peptide.
- 25 20. A purified polypeptide, the amino acid sequence of which consists of a polypeptide sequence of SEQ ID NO:30.

21. A purified polypeptide, the amino acid sequence of which is encoded by the ORF 14 from SEQ ID NO:2.

22. A method for preparing a polypeptide, the method comprising the step of culturing the host cell of claim 15 under conditions that permit expression of the polypeptide from the expression vector, and isolating the polypeptide from the host cell.

23. A method for preparing a polypeptide, the method comprising the step of culturing the host cell of claim 16 under conditions that permit expression of the polypeptide from the expression vector, and isolating the polypeptide from the host cell.

24. A fusion polypeptide comprising a polypeptide of claim 18 fused to a heterologous polypeptide.

25. A fusion polypeptide comprising a polypeptide of claim 19 fused to a heterologous polypeptide.

1. An isolated polynucleotide selected from the group consisting of:
 - (a) a polynucleotide with at least 60% identity to the polynucleotide sequence of ORF 39 from SEQ ID NO:2; and
 - 5 (b) a polynucleotide of ORF 39 from SEQ ID NO:2, with up to 30 conservative nucleotide substitutions;wherein the isolated polynucleotide encodes a polypeptide that is a spore surface antigen of *B. anthracis*.
- 10 2. An isolated nucleic acid consisting of the sequence of ORF 39 from SEQ ID NO:2.
3. A DNA construct comprising an isolated nucleic acid molecule comprising the nucleotide sequence of ORF 39 from SEQ ID NO:2 operatively linked to a regulatory sequence.
- 15 4. An isolated nucleic acid molecule comprising at least 100 contiguous nucleotides of ORF 39 from SEQ ID NO:2, that encodes a polypeptide that is a spore surface antigen of *B. anthracis*.
5. An isolated nucleic acid encoding a polypeptide which binds to the surface of *B. anthracis*, and having at least 60% nucleic acid sequence identity to:
 - (a) a nucleic acid sequence encoding the polypeptide of SEQ ID NO:82; or
 - 20 (b) a nucleic acid sequence encoding the polypeptide of SEQ ID NO:82, lacking its associated signal peptide.
6. An isolated nucleic acid encoding a polypeptide comprising an amino acid sequence at least 60% identical to a polypeptide sequence of SEQ ID NO:82, wherein the polypeptide that is a spore surface antigen of *B. anthracis*.
- 25 7. An isolated nucleic acid encoding a polypeptide comprising the amino acid sequence set forth in SEQ ID NO:82, with up to 30 conservative amino acid substitutions, wherein the polypeptide binds to the surface of *B. anthracis*.

8. An isolated nucleic acid that hybridizes under high stringency conditions to the coding sequence of SEQ ID NO:82, wherein said nucleic acid encodes a polypeptide that binds to the surface of *B. anthracis*.
9. An isolated nucleic acid that hybridizes under high stringency conditions to:
- 5 (a) a nucleic acid sequence encoding the polypeptide of SEQ ID NO:82;
- (b) a nucleic acid sequence encoding the polypeptide shown in SEQ ID NO:82, lacking its associated signal peptide;
- (c) a nucleic acid sequence of the ORF 39 portion of SEQ ID NO:82, wherein said nucleic acid encodes a polypeptide that binds to the surface of *B.*
- 10 *anthracis*.
10. The isolated nucleic acid of claim 9, wherein the hybridization occurs under high stringency conditions selected from the group consisting of:
- (a) 0.015 M sodium chloride/0.0015 M sodium citrate/0.1% sodium dodecyl sulfate at 50°C;
- 15 (b) 50% (v/v) formamide with 0.1% bovine serum albumin/0.1% Ficoll/0.1% polyvinylpyrrolidone/50mM sodium phosphate buffer at pH 6.5 with 750 mM sodium chloride, 75 mM sodium citrate at 42°C; and
- (c) 50% formamide, 5 x SSC (0.75 M sodium chloride, 0.075 M sodium citrate), 50 mM sodium phosphate (pH 6.8), 0.1% sodium pyrophosphate, 5
- 20 x Denhardt's solution, sonicated salmon sperm DNA (50 µg/ml), 0.1% sodium dodecyl sulphate, and 10% dextran sulfate at 42°C, with washes at 42°C in 0.2 x SSC (0.75 M sodium chloride, 0.075 M sodium citrate) and 50% formamide at 55°C, followed by a high-stringency wash consisting of 0.1 x SSC (0.75 M sodium chloride, 0.075 N sodium citrate) containing
- 25 EDTA at 55°C.
11. An isolated nucleic acid that hybridizes under high stringency conditions to a hybridization probe the nucleotide sequence of which consists essentially of an ORF 39 from SEQ ID NO:82, or the complement of thereof.

12. A vector comprising the nucleic acid of claim 1.
13. A vector comprising the nucleic acid of claim 5.
14. An expression vector comprising the nucleic acid sequence of the ORF 39 portion of SEQ ID NO:82, operably associated with a promoter.
- 5 15. A host cell comprising the vector of claim 12.
16. A host cell comprising the vector of claim 13.
17. A method of screening for a compound that binds to a polypeptide, the method comprising:
- (a) providing the nucleic acid of ORF 39 from SEQ ID NO:82;
 - 10 (b) introducing the nucleic acid into a cell and allowing the cell to produce the polypeptide encoded by the nucleic acid;
 - (c) contacting a test compound with the polypeptide; and
 - (d) determining whether the test compound has bound to the polypeptide.
- 15 18. An isolated polypeptide having at least 80% amino acid sequence identity to:
- (a) the amino acid sequence of the polypeptide shown in SEQ ID NO:82; or
 - (b) the amino acid sequence of the polypeptide shown in SEQ ID NO:82, lacking its associated signal peptide;
- wherein the polypeptide is able to bind to the surface of *B. anthracis*.
- 20 19. An isolated polypeptide comprising:
- (a) the amino acid sequence of the polypeptide shown in SEQ ID NO:82; or
 - (b) the amino acid sequence of the polypeptide shown in SEQ ID NO:82, lacking its associated signal peptide.
- 25 20. A purified polypeptide, the amino acid sequence of which consists of a polypeptide sequence of SEQ ID NO:82.

21. A purified polypeptide, the amino acid sequence of which is encoded by the ORF 39 from SEQ ID NO:82.

22. A method for preparing a polypeptide, the method comprising the step of culturing the host cell of claim 15 under conditions that permit expression of the polypeptide from the expression vector, and isolating the polypeptide from the host cell.

23. A method for preparing a polypeptide, the method comprising the step of culturing the host cell of claim 16 under conditions that permit expression of the polypeptide from the expression vector, and isolating the polypeptide from the host cell.

24. A fusion polypeptide comprising a polypeptide of claim 18 fused to a heterologous polypeptide.

25. A fusion polypeptide comprising a polypeptide of claim 19 fused to a heterologous polypeptide.

ABSTRACT OF THE DISCLOSURE

Novel bacteriophages of *Bacillus anthracis*, the nucleic acids of its genome, nucleic acids comprising nucleotide sequences of open reading frames (ORFs) of its genome, and polypeptides encoded by the nucleic acids, are described. Therapeutic and diagnostic compositions, methods and kits related thereto are also provided.

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FIGURE 1A: Polynucleotide Sequence of Phage Gamma (γ) (SEQ ID NO:1)

CTCAACTTCGCAGAAAAATCCGTTTTTGCATATTTTTTTAAGGGGTGTAATCATGGCTGGAAGAAATAACAACCACTC
TCTGTTATACAGGAAAAAGGTAGATCAAAATCACATTACAAAAAGTGAGAAAAACAGACGAGAAAAACAAGAAGCATT
GCGGGGCATACGTATAAAATGAAGCTCCTTCTTATTGACTGCAGCACAAAAAAGGAATTCGATACTTTAGCTGCTG
AATTAGTCAGATTGAAAATTTTCAGTAACCTAGATGTTGACAGTTTAGCAAGGTACGTTGATTCTAAAGACCAATATATA
AAAAATGGTTCTGCTAGCTAAGAAAAACAAACCTTCAGATGACTTTAAATTTGATTCTCAATGCAAGAAGTAAAAATCT
TTTATTCAATGAATGCCGTTCTTCAGCTAGTGATTTAGGTTTGACCATTAACATCCCGCTTAAATAGTTATTTCCAGAAG
TAGATACTTCACAACAAAAGCAAAGTGAAGCGCAAAAGCGTTTTGGTGATCGTATATGAACCTGGATAATGGAACGGGTTT
TTGCATATGCGAGGACATTTTAAACGGCAAGATAAATAGTTGTAAAAAACATCGTTGGGCCATTGAACGATTTATAAGG
GATTATGAGGAGTGTCAAAGTGAAGACAGTCCTTTTTTATTTTGATGAGAGATAGCGGAGGATTTTACTGTTTGCAAA
GGAATTTAAGCACGTTGAAGGGATTTTGGCAGGTGAATCCGTAGAAATTAAGTATTTCAATTGTTTCTAGCGGCTAATA
TTTTCGGATTCAAAAAGAAAATAAATGGAGCAAGGCGATTTAGAAAGGTTTTTATTCAGTTAGCGCGTAAAAATGCTAAA
TCTCAGTTTCTTGCTATTGTAGCAGCTTTTTGTACATTTCTTGGAGACGAAAAACAACGGGCTTATATTGCTGGATGGAC
AAGAGACCAATCATCTGAAGTTTATGAAGCTGTAAAAACAGGGATTAGTTCTAGTGAATTGTTAGAAGGTAAATGGAAG
AGGCTTATAGTACCATTGAAATATTTAAGAATGGTTTCAGTTGTCGTTCCACTTTCAAAGAAGCTAGAAAACTGGTGAT
GGTAAAAACCGTCTCTGGAAATTTGTCGATGAATATCATGCACATGAAACTGATGAAATTTAGCGTTTATCTGCTGG
TATGGTGGCAAGGAAAGAGCCGTTAATGTTTATCATAACAACAGCTGGTTTCGACTTATCAAGACCTTGTATAGAGAGT
ATGAGTATGTCTAGTACATCTTAGACCCGTCAAAAATGTAGAAAAACGATGATTATTTCTGTTATGATCTGTGAATTGGAA
AAGAACGATGATATCAAAGATGAGTCGAATTGGATAAAAGCAAACCCAAATCGTAGCTACATATGAAGAAGGTTTGAAGG
TATACGTTTCAGATTGAAAGGTTGCTCTTGATAGACCTGAAAGATGAGGGCTTTTAAACCAAACATGAAATGCTTGGG
TCGATAAAAAAGGACAACGGATACATGGATATGTCAAATGGCAAAATGCGAAGTAGATACCTTTGATTTTTCAGGTGCG
ACTCTTTGGATAGGTGGCGACTTATCAATGACAACAGATTTAACTAGTGTGCGTTGGGTTGGAATGGACGATGAAGGTGA
TTTTATTTGTTGGACAACATTCTATTTATGCTGAAGCAGCTTTGAAAGAAAAGATGCGCATAGATAAGGTGCGTTATGATT
TATGGGCCGAACAAGGGTATTTAACTTTAACGCTGGTGAAATGGTTGATTATACAATTTGTTGAGTCTTGGATAGAAAA
TTTTCAAAGACAAAGAAAATCAAGAGTTTGATTACGATTAATGGAATGCGTTACATCTAGCACAAAATTTAGAGAATAA
AGGGTTCTGTTGTGTAGAAATCCCTCAAAGGATTGCTAATTTATCCATTCCGACTAAAAATTTTCGAGAAAAAGTATACG
AAAAGAAAGTTAAACATAATGGAGATCCAGTCCCTTTTTTGGGCGCTTAATAATGCTGTTGTTAAAATGGATGATCAGGAA
AACATTATGATTTTCAAAAAAATAAGTAAAAATCGTATTGATCCAGCAGCAGCGGCTTAAATGCAATTTTCTAGGGCTAT
GTATGGAGCAAGTGTGAGGTTTGTATGTTATGCAATTTGCAAAATAAGACTTTCTAGGCAAGTTATGGAACCTAGGGAGGGG
GTGAACATGTGAAGATAGTGGATTCTGTTAAAAAGTTCTTTAATTTTGA AAAACGCCAACGTCGCAGGTAATAGAGTTG
AATAAAGACGATGAAAAATTTAGAAATGGCTAGGGATTCTCCAACTACTATTAGCGTTAAAGGAAAAAATGCTTTAAA
AGTTGCTACAGTCTTTGCTTGATCAAAATCTATCTGAATCCGTATCAAAGTTACCGTTGAAAAATTTATCAGGAAGATG
AATATGGAATCCAACGCGGTACAAAGCATTATCTCAACAATTTACTGAGACTAAGGCCAACCCTGATATGTTCCAGTATG
AACTTTTTCGGATCATTTAGAAGCTCAAAAAAATTTATATGGCAATAGCTACGCTAACATAGAGTTTGTATAGAAAAAGTAA
AGTCCAAGCGTTATGGCCGATAGATGCTTTAAAGTGACAGTATACATTGATGACGTTGGTTTATTAATTTCCAAAACCTA
AAATGTCGTATGTAGTAAATACGGGTGGACAACAAAGAGTGTTAAAGCCAGAGAGATACTGCACTTTAAAAACGGAATA
ACTCTTGATGGTCTTGTCGGTGTTCTACAATGGAATATTTAAAGTCTACATTAGAAAAATTCAGCTTCAGCTGATAAAT
CATAAATAATTTTTACAAACAAGGGTTACAGGTAAGGGATTAGTTCAATATGTGCGTGATTTAAATGAAGATGCGAAAA
AGGTTTTCCGAGAAAAATTTCAATCAATGCTAGCGGCTTTCAAAATAGCCATCGTATTGCATTAATGCCAGTAGGATAT
CAATTTCAACCTATTTCATTAAATATGTCAGATGCTCAATTTCTCGAAAATACCGAATCTACTATAGGCAAAATCGCTAC
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TCTATACCGATACATTACAAGCGACTTTAACAATGTATGAGCAAGAAATGACGTATAAGCTATTTTAGACAGTGAGTTG
GATAAGGGGTTTTTATTCAAAATTCATGTAGACGCTATTTTAAAGAGCGGATATCAAAACGAGATATGAAGCTTACAGAAC
GGGTATTCAAGGCGGTTTCTTTAAACCTAACGAAGCTAGAAGTAAAGAAGATTTACCAACGAGAGCTGGTGGGGATCGTT
TACTTGTTAAATGGAATATGTTGCCGATTGATATGGCTGGACAGGCATATTTGAAGGGAGGTGATACTAATGGAGAAAGTC
AGCAAAGAAGGAAATGAAGGAATTAGAGCTTTGCCAATGACTATTGAAGTCCGTGAAGTTAATGAGGACGAGGAAAAAC
GAACAATTTCCGGATCGATAAAATATAACAATGAAAGTCCGGAATCGTGACTGGTGGGGCGTATTTTCGTAGAAGAG
ATTGCTGAGGGAGCTTTGATGAAAGTTTAAAGTTCTGATGTTGAGGTTTTATGGTCTCACGACACATCTCAAGTATT
AGGAAATACTAAAAGTAAACTTTACGAATCGAAAATGACAAGAAAGAAATTACGATTTGAATTAGATATTCCTAATACAA
CTGTTGGGAATGACGCATGGGAATTAATTAAGCGTGGAGATGTTGATGGAGTTTCTTTTGGGATGAAGGTTACAAAAGAC
AAATGGTCATCGGAAGAAGCTGAAAATGGAAGCTTTATAAGCGTTTCGATTTTAAATGCTGAACCTATATGAATATCACC
GGTTGCAATCCCTGCATATCCAACGAATGAAGTAAGTGACGTTTCATTTGGATGATTTTAAAGCTGGAGAAAAGCGAGTAG
CTGATGAGTTTAGGAAAAGAAAACCTACAAATCGAAGTACGCTTATATAAGGCTCTTTTTTTTATTGATAAATTTAAGGAG
TGATTTGAATGTCAAAAGAATTACGTGAATTATTAGCTAAGTTAGAAGGGAAAAAGGAAGAAGTACGCTCTCTTATGGGA
GAAGATAAAGTGGCAGAAGCAGAACAAATGATGGAAGAGTGCGATCACTTCAGAAAAAATGATTTTACAACCGCTCATT
AGATGAAGCAGAAACCGAAGAACGAAATAATGGAAGAGAAGTTGAAACACGTAATGTAGATGGTGAATGGAATACCGCG

ATGTGTTTATGAAAGCATTACGCAATAAACCATTAAATGCTGAAGAACGTGAATTTCTTGAGGATGATTTAGAACAACGT
GCCATGTCAGGATTAAGTGGGAAGATGGAGGACTTGTCTCCCTCAAGATATTCAAACGCAAAATCAATGAATTAGCTCG
TTCATTTGATGCGCTTGAGCAATATGTAAGTGTGAACAGTGCCTACAGGTTTCAAGATCAGGATATTAGAGAAAAAT
CAGATATGATTCGCTTTGCTGAAATCACTGAAATGGGTGAAATTCAGAACTGATAATCCGAAATTTTCAAATGTACAA
TATGCAGTGAAGGACAGAGCAGGTATTTTACCGTTATCTCGTTTCAAGATAGTGATCAAAACATCCTAAAGTA
TGTGACTAAATGGCTAGGTAAGAAATCTAAAGTTACACGTAATGTGTTAATCTTGGGCGTAATTGAAAAGTTAAACAAAC
AAGCAATCAAATCTCTGGATGATATTAAGATGTATTAATGTAAATTAGACCCAGCGATTTCTCCGAATGCGATTTTA
CTTACAAACCAAGATGGATTTAATTATTTAGACAAATTAAGAGTAAAGACGGAATAATATATTTTACAGTCAGATCCAAC
GCAAAAAACAAAAAATTTTGTCTGGTACTAATCCAGTCGTTGTTGTTTGAATCGTTTCTTAAATCAAAGGGAACCTA
CAGCTAAAAAAGCGCCACTTATTTATGGTGATTTAAAGAAAGCTATTGTTTTATTTAAACGTGAAGATATGGAACCTGGCT
TCTACAGATGTAGGTGGTAAAGCATTCACTCGTAATACATTAGATTTACGCGCAATTCACAGTGATGTGCAAAATGTG
GGATAATGAAGCAGCAGTTTACGGAGAAATCGATTTAAGCGCTCTGTGTAACAACCTCAAGGTAACTAAGGAGGCAT
TTGAATGCTTTGTTTACCTTAGAAGAAGCTAAAGAAATGGATTGAGTTGGAGCGGAGACGATGACCCCACTATCACTGTAA
TTAAAGCGGCTGAATTATATATTTACAAAGCACTGGCAAAACATTTACTCAAAACAAATGAAGATGCTAAGTTGCTTTGT
TTATTTCTGGTGGCTGATTGGTACGGAAATCGACTACTTGTAGGTGAAAAAGCCAGTGAAAAAATCAGAACCATTTGTTCA
GAGTATGATATTACAGCTCCAATATGCTTCAGAGCCTCAGGAGGAAAGAAAAATGAATCCTGCAAAATTAGATAAACGGCT
TACATTTCAATGATAAGATGAAAAATGCAAAAGGGCTTACGGGTGATCCGATAGATAGGATATAAAGCTCTTTTACCGTAT
GGGGCTCTTTTGTATTATTTAAAGGGAAGGAAATACTTTGAGGCAGCAGCTGCTAATAGTGAGGTTCAAGGAGAAACAGAA
ATCAGAAATCGGGATGATGTAAGTGCAGATATGAAAAATTAAGTACAAAAACGTGATTTATGATATTGTTTCCGTTATTCC
AACTCAAGATCATACTTTATTAATCATGTGGAACCGTGGTGAATGAATGGCTGATGGTATAGATTTAGATTTTATTAGGA
TTTGTAGCTTTAGTTACTGAATTAGACCAAAATGGGCTTACGGGTGAGAGAAAAATGAAGATAAAGCTCTTGACGCTGGTGG
TGAACCTATTTCGTAAGGCATTGCAGAACGAGCGCCAAAGAAGCCCAAGCCCCAAAAACAGATCTAAAGTGAACCGTGGC
GTACAGGGCAACATGGTGCAGACCAGATAAAAGTAACAAAAGCTAACTTGAAGGTGGAATAAAAAACAGTAAAAATAGGT
CTTAATAAAGCGGATCGTTCCCGCTGGTTCTATTAAAGTTCCATGAATGGGGTACATCCAAATGCCAGCACATCCATT
TATAGAGCCGGGTTTTAATGCTTCAAAGCGGAAGCTGTACGCTGCTATGACAGATATTTAAAGAACGAAATGAGGTTGG
ATTTGTGATAAAATTAAGACCTGATATTTTACAAGCTTTGAGAATGATCAAGAGCTTGTTCATTGTTGGGTGGGAAAC
GAATTTATTACCGTAAAGCAAAGAAGGCAGAAGAGTTTCCGCGAATTACGTATTTTGAATTAGACAATAGGCCAGATGGA
TTTGCAGATAATCAAGAGATTGAAAGTGAATCTTGTTCAGTTGATGTTTGGGCAAGAGTAGTACAAACAGCAATCCA
TCAAAAGTGAATGAATCATGAAAAGAAATGGTTCCTCAGCTATGCGGTTGCTGATTTATATGAAGAGGATACACAAA
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ATTCGAAATGTTTGGCATGTTTGTCTGCACAAATTACCTAAAACTATATCTGTATCTGTTTCTGCTGCAATGCAAGCTAAAG
CAAGAAGAGGCGAGTTTATTGGAAAAACGGGATTAGGATACGATGTAATTGACAAGAAAATTTGTTATCAATGAAAAGGAA
GCTGAAATGTGAAGGAAAATTTTGTATTTATCTTATAAAGGCTATGGATTAAAGAAAAATAGCGAATATCTTAAACGATAA
AGGCACATATACGAAGTTTGGCCAGTTATGGTTCGCATCAACTGTAGGGAAGATTTTAAAGAACCGAGCAATGATATTAA
ATTTGGTCTTTAAATGTTATAAAACAGTAAAGTAGAGCGGATTATCTATGGATTGAAGCAGCAAGAAAAAGAACTAGAGAT
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AACAAAACAGATACAGAAATGAATTTAGAGGAATGATGTTTGTAAACATTTGTTGGTGAGCCAATTACAGCTAAGTATT
CAGGTAGATACGCAAAAGGAAGTAAAAAAGAGTGGGTATATGAATGCAGTAATTATATTAGATTCAATCGCTGCGTT
AACTTTGACCCGGCTCATTTATGATGATATAAGAGAGCGGATTATCTATGGATTGAAGCAGCAAGAAAAAGAACTAGAGAT
ACATTTTCAATCAAAAAATGCATCAAAAAAGAAATGATAAATCTACAGAAATTAAGAAGCAAAATTAAGTTGTTAAAGTGGA
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AATGAAATTAAGAGCAAGAGTTGCGATTACTTAAATTAACAGATCAGAATAAGAGAAATAAGAAGAGAAAAAAATTA
AGAAGCTTTTCAATGCTCGATGAAGAAAAAGATATGCAATGAGGTTTAAAACTTTAATAAAGAAAAATCAACATTAGTA
AGGATAAGTATATCGACATCGAATATACATTTCTTTATAGTTTAAAGTTGGTTATTAGTTACTGTGATACTACCTGCA
GTAAACACCGATAGCTTGTCCAAGATCATGTTGTGTTAAATTCGTTCTCTTCGTAATTGACGTAACCGATCTTTAAATTC
CACAATAATCACCTCATAAGTGGTTGTTAGGATTATTATAATATTTCTTAAAGGAAAAATCAATCCGAGTTATTTCTAA
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TTCAGGTGTGCCGATGGACGAAGGGGAAAAGCTTCAAGAACAAATTAATAAGGTAGTTACAGAATGGCTAAAAGGAATAA
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GCGCTCCTTAAGAAAAATAAAAAAGAAATACCTCATGATCTGTATGTATGTTTTTTAGGAATGTGAGGATTTAAAAACA
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CACGGAATTAGAATGAATTTGTTAAGGAAGGAAGTAAAAATGAGGGCTTGAAGAAAAAACATGTTAAAGAGCATT
TTTGAATCGTCAAAAGGAAATTTGATAAAGAACGGACTGTCAGCTTGGAGAAATATTTTGTGAAATCAGGAATCATAA
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AAGTAGGTGAATCATCATTTGTTTAACTGGCTGAGAGATTACCAAAAGTTAGAAGAAGACATAGCCTATCTGGAATACAA
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AGTAACACAACCTCCCTAATCGTATTGAGAAGTGTCTTTTATTGTCTCTCATGTAAATCATGAACATATAGCTGCGTACG
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CATTGGTGTTTAGATAGAACTGCGGATTTGAAGAGACTTCTCATAAGGTACGTGATGGTTGGAAATGTCCTGATTGTAA
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ATGTCACAACAGAAAAACAGCAGAAGACAAAAAGAAATACGGGTAGGGGCGGGTCGAAAAACATTACAGGGCGGTCTGTCC
GTACcgccgcccc

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FIGURE 1B: Polypeptide Sequences grouped by open reading frames (ORF) of Phage Gamma (γ)

Orf1 (SEQ ID NO:3)

MAGRKNQPLSVIQKGGRSNHITKSEKNRREKQBEALRGHTDKIEAPSYLTAAQKKEFDTLAAELVRLKIFS
NLDVDSLARYVDSKDQYIKMVRLLRKTTPSDDFKLYSQMQRSKNLLFNECRSSASDLGLTITSRLKLVPIE
VDTSQKQKSEAQRFGDRI

Orf2 (SEQ ID NO:5)

MNWIMERVFAICEDILNGKINSCKKRWAIERFIRDYEECQSEDSPPYFDGEIAEDFYWFAKEFKHVEGI
LAGESVELTDFQLFLAANIFGFKKINGARRFRKVFIQLARKNAKSQFLAIVAACTFLGDEKQRAYIAG
WTRDQSSVEYEA VKTGISSESELLEGKWEAYSTIEIFKNGSVVPLSKARKTGDKNP SLGIVDEYHAH
ETDEIYDVLSSGMVARKEPLMFIITTAGFDLSRPCYREYEVSDILDP SKNVENDDYFVMICELEKNDDI
KDESNWIKANPIVATYEEGLEGIRSDLKVALDRPEKMRAPLTKNMNIWVDKKNNGYMDMSKWQKCEVDTF
DFSGATLWIGGDLSTTDLTSVGWVGMDDEGDFIVGQHSFMPPEARLKEKMAIDKVR YDLWAEQGYLTLP
GEMVDYTIWESWIENFSKDKEIQEFDYDKWNALHLAQNLENKGFVCVEIPQRIANLSIPTKNFREKVYEK
KVKHNGDPVLFWALNNNAVVKMDDQENIMISKISKNRIDPAAAVLNAFSRAMYGASVRFDVSEFANKDFL
GKLWN

Orf3 (SEQ ID NO:7)

VKIVDSVKKFFNF EKQTSQVIELNKDDEKLEWLGISPSTISVKGNALKVATVFACIKILSES SVSKLPL
KIYQEDEYGIQRTGKHYLNNLLRLRPNPYMSSMNFPGSLEAQKNLYGNSYANIEFDRKGKVQALWPIDASK
VTVYIDDVGLLSKTKMWWYVNTGGQQRVLKPEEILHFKNGITLDGLVGVP TMEYLKSTLENSASADKFIN
NFKQGLQVKGLVQYVGDLNEDAKKVFRNFESMSSGLQNSHRIALMPVGYQFPQISLNM SDAQFLENTEL
TIRQIATAFGIKMHQLNDLSKATLNNIEQQQQQFYTDTLQATLTMYEQEMTYKFLDSELDKGFYSKFNVD
AILRADIKTRYEAYRTGIQGGFLKPNEARSKEDLPPEAGGDRLLVNGNMLPIDMAGQAYLKGGDTNGEVSK
EGNEGN

Orf4 (SEQ ID NO:9)

MEKSAKKEMKEIRALPMTIEVREVNEDEGKRTISGSIKYNNESAEMRDWWGDTFVEEIAEGAFDESLKVRD
VVGLWSHDTSQVLGNTKSKTLRIENDKKELRFELDIPNTTVGNDAWELIKRGDVGVSFGMKVTKDKWSSE
ERENGKLYKRSILNAELYEISPVAFPAYPTNEVSVRSLLDDFKAGEKRVADFRKRKLQIELELI

Orf5 (SEQ ID NO:11)

MSKELRELLAKLEGKKEEVRSMLMGEDKVAEAEQMMEEVRS LQKKIDLQ RSLDEAETEERNNGREVETRNV
GEMEYRDVFMKALRNKPLNAEEREFLLEDDLEQRAMSGLTGEDGGLVIPQDIQTQINELARSF DALEQYVTV
EPVRTRSGSRVLEKNSDMIPFAEITEMGEIPETDNPKFSNVQYAVKDRAGILPLSRSLQSDQNILKYVT
KWLKKSKVTRNVILGVIEKLTKQAIKSLDDIKDVLNVKLDPAISPNAILLTNQDGFNYLDKLDKDGKY
ILQSDPTQKNKKLFACTNPVVVSNRFLKSKGTAKKAPLIIGDLKEAIVLFKREDMELASTDVGGKAFT
NTLDLRAIQRDDVQMWDNAAVYGEIDLSAPVEQPOG

Orf6 (SEQ ID NO:13)

MLVTLEEAKEWIRVDGDDPTITMLIKAAELYIYKATGKTFQTNEDAKLLCLFLVADWYGNRLLVGEKAS
EKIRTIVQSMILQLQYASEPQEERK

Orf7 (SEQ ID NO:15)

MNPAKLDKRLTFQVKDENAKGPDGDPIDGYKDAFTVWGSFVYLKGRKYFEAAAANSEVQGETEIRNRDDVS
ADMKIKYKNVIYDIVSVIPTQDHTLLIMWKRGMNG

Orf8 (SEQ ID NO:17)

MKLTLMINKEKQTFNMPEFIPARLIRQAPELAEIPNNPGPEDMDKMVQFVVKVYDQGFTLDQYWDGVDARK
FLSTTSDVINAIINETVEAAGGSTESGEEENPNA

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Orf9 (SEQ ID NO:19)

VINLRPDILQALENDQELVSLGGKRIYYRKAKKAEFFPRITYFELDNRPDGFADNQEIESEILFQVDVWA
KSSTTAIHQKVNEIMKRIGFSRYAVADLYEEDTQIFHYAMRFAKGVEL

Orf10 (SEQ ID NO:21)

MAGEVVRISSTVGVDNLVYAKVLQDDSSAIKYTDVKKMEGAVKVKLTKKVASEVMWSDNRKSEIAESDGET
EVEIEVRGLSLSTKADIEGFPEVKDGLDEKREGEKPYLAIGFRFLKANDKYRYVWLLKGKLSQEBEEAET
KKDKPNFQTTKLKGSFIERDFDRTKFTADEDEPTFTKLVDGNWFKVYEKPVTPPAGK

Orf11 (SEQ ID NO:23)

MKLTLMINKEQTFNMPFIPARLIRQAPELAEIPNNPGPEDMDKMVQFVVKVYDQGTLDQYWDGVDARK
FLSTTSVDINAIINETVBAAGGSTESGEEENPNA

Orf12 (SEQ ID NO:25)

MDELYLSLLRQGYKHHHIDNEMDIWHYLRRLNRKMHENGNNENYEGSNSNEIEVPAENII

Orf13 (SEQ ID NO:27)

MANEINNLVVRLSLDNVNRQGISNSGRAVRTLQNELKSVSTGMGGFANASQOTQAKMNTLSRLIDAQKEK
VKALRQAYDQNKAKLGENDAATQRYASQVNKAVADLNRNFENELKQVNRQAEQKGMKLNNSLKSLQAEFQS
ITTMGGGFSNATEQTRAKVDVLSRMVDKQKEKIRELQAYNRAKTEEGEASQSAQRYAEQIHRATAELNRF
ETGLQQSNRELEQQGNRLNLFNGRMETLGNHLQNAQMIGMVFPGMTYAI GRGLKSAITESMNFEEQMANV
KAVSGSTGAEMKKLSELAVNMGETTKYSSVQAGQIEELIKAGVSLQDIINGGLAGALNLATAGELELGEA
AEIASTALNAFKADHLSVADAANILSGAANASATDVRELKYGLSASSAVAAGAGMTFKDTATTLAVFAQNG
LKGS DAGTSLKTMMLRLNPSTKEAYNKMRDLGLITYNAQAGDFDLVKNGIQPASRNVGDI EVALEQYVMKT
EGVTWKNDKCDTTFRELATSSAFLSSKFYDQQGHIQSLENI SGT LHESMKDLTDQQRSMALETLFGSDAVR
GATILFKEGAKGVNEMWDSMSKVTAADVAATKIDTLKGRLLTLLDSAFSTMKKTIGDALAPVVSFVAGLQK
LVDGFNSLPGPVQKAIITGGIVLALTAVATAIGVVLAAFGM IASGIGSLALASVGGIAGIAGAVGFL
GSALAVLTGP IGLVAAALIGTG VVAYKAYQKATEDSIASVDRFATNTEGKVSSSTKKVLGEYFKLSDGIRQ
KLTEIRLNHEVITEEQSQLIGQYDKLANTIIEKTNARQQKEIEGLKFFADS YVLTAAEENKRIEQLNQH
YEQEKLTQEKENKIKEILQTAARENRELTTSERISLQALQDEMDRVAVEHMSKNQMEQKVILENMRVQAS
EISARQAAEVVENS AKARDKVIEDAKTRDEKIAEAIQRDENKTTITADEANAI IAEAKRQYDSTVSTARD
KHKEIVSEAKAQAGEHANQVDWETGQVSKYQAMKDDVIRKMKEMWSDVTNKYEDMKNASANKVEIKNTV
SRKFEEQKKAVTDKMSEIKSSIEDKWNTEKFFSSINLRSIGKSIIEGLGKGI DDASGGLFSKAAEIASDI
KKTISGALEINSPSKVMI PVGS AVPEGVGVGM DKGKRFVVDAAKNVVGTVKKQMGMNMP SVFDFG FQTNQYS
IPQNTFSDFSGYMQPQLSYNNPSMAKTI FPNRPGGEQELNLTVMNTNVLDGKELANGSYTYTTKLQNRQK
RRAEF

Orf14 (Tail fiber) (SEQ ID NO:29)

LGKLSFTFNNIRKDYIQMLVGRKRPSWAPVKRRLVRVPHRAGALLNTETETERRIDVPLVIKAKDMADLQ
KLKEDLADWLYTEQPAELIFDDELDRTYLALIDGSVDLDEIVNRGRGVITFVCPMPYKLKGTNTHKFTQEW
STETTSYFTNKGSV EAPALIEMTVKKPSTFLDVWFGEYPNNRDYFRIGYPLTVEETTQERERVWDEMAT
PIGWTPVTGQFDDMKGTGFSKSRGGYALYCEDYGDVGFYGAIAKKNIPGGPLQDFEMEAWMTLKS KNIGE
MGRVEVLLLD EASN VVARINMNDLYATAEITRAHMKIGNSGTPNSFRKLVDTS GYYSNTFNQFRGLRIAR
RGKVSVSYVAKFIDGTEKD GASLVERWIDETGNPMTERKIAQVMIAICKWDNHQPVNEIQIDDLKFWKVNK
VPSNAQPYIFDTGDKIVIDTEKSLVTINGKNAINIKEIFSNFPVIIRGDNRIDIMPPDVNATISYRERYR

Orf15 (SEQ ID NO:31)

MRTPSGILHVVDFTDQIVAAIQPEDYWDKRWELKNNVMDLDFTAFDGTDHAVTLQQQNLVLKEVRDGR
IVPYVITETEKNSDTRSITTYASGAWIQIAKSGI IKPQRIESKTVNEFMDLALLGMKWKRGITEYAGFHTM
TIDEYIDPLTFLKKIASL FKL EIRYRVEIKGSRIIGWYVDMIQKRGHDTGKEIELCKDLGVGTR IEHTRNI
CSALVGFPVKGEGDKVITIESINKGLPYIVDADAFQRWNEHGQHKFGFYTPETEELDMTPKRLLTLMEIELK

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KRVNSSISYEVEAQSIGRIFGLEHELINEGDTIKIKDGTFTPELYLEARVIAGDESFTDSTQDKYFEGDYR
EIVNQNEELRKIYNRILSSLGKQEMIDQLDRLVQEANETASNAKKESEAAKTLAEKVQENIKNNTVEIIE
SKNPPTTGLKPFKTLWRDISIGKPGILKIWTGTAWESVVPDVESVKKETLDQVNDIATTKTELNQKVQEA
QNQATGQFNEVKESLQGVSRITSNVENKQGEIDKKITKFEQDSSGFKTSIESLTKKDTESISNKLNTVESTV
EGTKKTISEVQQTNDLKKKTEIEEKAGKITEKLTSLRETVNRVNYVINSDFSNVTNSWIGITNATLKF
FVDVNISEASAIKKGLQITSNAKFVYQKLPADVFKKKGIASCYINVSSFTPGTDYPRLYMRFTYDONGTE
KQYYAILKQOEVTNGWIRISIPFDTTGYTGELKEVRVNIATADTTTIDATFTGIMVTFGDLESWNLAPED
GVTQGVFQSKTTEIEKSVDGKVTVTNVQNSQAGFEKMSNVEQTATGLSSTVSNLNNVSDQGKKLTEAN
TKLEQQATAIGAKVELKQVEDYVAGFKIPELKQTVDKNKQDLLDELANKLATEQFNQKMTLIDNRFTINEQ
GINAAAKKTEVYTKTQADGQFATDSYVRDMEXRLQLTEKGVSI SVKENDVXAANMSKENIKLNAARIDL
GKVNKEWIKAGLLSGCQIRTSNTDNYVSLDDQFIRLYERGVARAFLGHYRRSDGAVQPTFILGSDEKTNAP
EGTLFMSQAGAGWSGAYASIGISNGIVDGAQVQSVYWELOQRNGLSVLNANDYHVFYAGNGNWYFRGKPG
YQTSLVVEDNSTDSDLRLPNVTIRNSRAAGYTGVIQLKSPVTQNGWGAQGNFMTPSLREYKSNIRDISFS
ALEKIRSLKIROFNKYKNAVNELYRMREEKSPNDPPLTTEDIKTYGYLIVDECEDEMFVDESCKGIHLYSYAS
IGIKGLQEV DATVQEVEIANLKSQIASQEDRIARLEBELLQQLINKKPEQP

Orf16 (SEQ ID NO:33)

MDRIDVLLKAFIAAFGGFCGYFLGGWDATLKILVTMVIDYLTGMIAAGYNGELSKSVGFKGIKKVVLFL
LVGAAQLDSALGSNSAIREATIFFFMGNELLSLENAGRMGIPLPQALTNAVEILGGKQKQBEKKGDVQ

Orf17 (PlyG lysin) (SEQ ID NO:35)

MEIQKKLVDP SKYGT KCPYTMKPKYITVHNTYNDAPAENEVSYMISSNNEVSFHIADDDKKA IQGIPLERN
AWACGDGNGSGNRQSISVEICYSKSGGDRYKAEADNAVVDVVRQLMSMYNIP IENVRTHQSWSGKYCPHRML
AEGRWGAFIQKVKNGNVATTSP TKQNI IQSGAFSPYETPDVMGALTS LKMTADFILQSDGLTYFISKPTSD
AQLKAMKEYLDRKGWYEVK

Orf18 (SEQ ID NO:37)

MMKYKKLISICIGSTLLLGLTACDSSKQSESSEKTNVKSQPETKKDLTSQDELNKKIKQDAEEVSFVKAN
GDQYKKGKRLKATGTVDLLKSSALPSFVISTNENDGKGYMTIQIVQSGVQTNENEITLKNGLKISKGSI
VTIYGAYDEKDKTGMPKISATVIEQ

Orf19 (SEQ ID NO:39)

VRKCKLRVIFAEREIRQKEFSKLIGISQTTMSSLVNNTLTPTFLTAYKIAKELKLHMBEIIWIEBENENV

Orf20 (SEQ ID NO:41)

MRWQYNHLNTPYHLHPSKELCSMYNGSRSRATESILNHMKNHVEYDRKEYKGYFSLSQVLEEDLYGEEED
VLNWEILMDCYDVVLTRKGIAPFREKEEEQA

Orf21 (SEQ ID NO:43)

MTLAGEAIIWTATGLSVVAMKAAEKMGKSVPHNLPRVTLYTTLTGSLYLLRYVLVLFL

Orf22 (SEQ ID NO:45)

mwklfipyvirslacMHVFLETGIYTLYKRDIRSDFMLELLSVPFAGLIFAIVGERLKGRESDRKKIQVFF
EVSGIAIRREDKLQYPVFLQEKEDDRSTTYIYRLPVGMPSKIIQKVEDVVSEGLSKPVRIYDNYKLNIRV
FHRDIPKKWSWSKGLVAEGSWCVPMGQSLEKLIYHDFDKTPHMTLGGLTRMGKTVFLKNVVTSLTLAQPEH
INLYIIDLKGGLFPGPYKNLKQVVSIAEKPAEAFMILTNI LKKMEEMKMEYMKCRHYTNVETNIKERYFII
VDEGAELCPDKSMKKEQORLLGACQQMLSHIARIGGALGFRLI FCTQYPTGDTLPQVQKNSDAKLGFRLP
TOTASSVVIDEAGLETIKSIPGRAIPKTDRLTEIQVPYISNEMMWEHLKGYEVEKHEDANAYANQPSNGDT
CDD

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Orf23 (SEQ ID NO:47)

mrwrnmrmqthmqinrqmailatirkqlqfatrrhlmsiHEMGGIRNANRILKDLSIYTSKVYVYNKEHVYYL
NQSGHKLFGEQKVVHGHGVTHALLRNEAWLNLYCPDDWQVETEI KYIKDNKKKKIIPDVKFRDEDRILHAV
EIDRTQKMIVNDEKLKKYEELQIYKQKHNGKVPVHFFITITKYREKLEELANKYVNFVKVYVIATT

Orf24 (SEQ ID NO:49)

MKFTLGNSLDELGITKNKLSTESQVRYNTISDLVNGNANAVRFDSEAIIDALNAIAAEKGINKIYKIDDV
IQYIKKS

Orf25 (SEQ ID NO:51)

MAFKASMIASSESKRTALALPFTKSLIVLYLTWDSVDNLFLVIPNSSKEFPSVNFILFSSAALVILYSFY
NINRN

Orf26 (SEQ ID NO:53)

MLSSANYTQYKKLQSFERSVEEMNEAICSFYKHTHELSESAIKVLKFLARHSCKIPGVSFLKVGTTAEALN
ISDRTVRRVLKVLEDFEVVTRHKTIRTEGKLRGGNGHNVYVLLKKYSVTPNVLPKMSQRQDEENLTESKVS
DTKTDKEAKLSESHPLEELKSELNVKETSARESKEIELEDLDETFTPENVPVSQFRDVPVAPFFKSADKIYKL
YHRVLIAYKRSKIDKPIEQVINQAIQAFKETVFAEKANKIRSTFEGYFYRIVESKFMERRKECRGLLFDW
LNE

Orf27 (SEQ ID NO:55)

LKYAVYVRVSTDREQVSSVENQIDICRYWLEKNGYEDPNAVYFDDGISGTAWLERHAMQLILEKARNE
LDTVVFKSIXRLARDLRDALEIKEILIGHGIRLVTI BENYDSLYEGGNDIKFEMFAMFAAQLPKTISVSVS
AAMQAKARRGEFIGKPLGYDVIDKKLVINEKEAIEVREIFDLKYGYGFKKIANTFLNDKGTYYTKFGQLWS
HTTVGKILKNQTYKGNLVLSYKTVKVDGKKRVYTPKERLTI IEDHYPTIVSKELWNAVNSDRASKKKT
QDTRNEFRGMMFCKHCGEPITAKYSGRYAKGSKKEWVYMKCSNYIRFNRCVNFDPAHYDDIREAIIYGLKQ
QEKELEIHFNPKMHQKRNDKSTEIKKQIKLLKVKEKIDLYVEGLIDKEMFSKRDNLNFENEIKEQELALL
KLTDQNKRNKEBKIKFAFSLDEEKMHEVFKTLIKKITLSKDKYIDIEYTFSL

Orf28 (SEQ ID NO:57)

VIIVEFKDRLRQLRRERNLTQHDLGQAIGVTAGSITVTNNQL

Orf29 (SEQ ID NO:59)

MKVIKDETKLKAAPKKSQYKYQELADELEISCSYCYKLINNHNYKKKISYNLASRMAHVNLNASVVDLFEEQ
VDFF

Orf30 (SEQ ID NO:61)

MREHRGERAMSEIYYKGFIIKETYGERNIEEVFKEAYESFYGVEVKVVKELGTRKNSAAS

Orf31 (SEQ ID NO:63)

MDQLTVASELRLLGRRKRVAGYEFTGIEGGFGEQKAMLVLDIATIHNPKEINRRINDNRIRFKDGVDIV
DLKSGGFNPPQLNLGFSNMQIAKSNNIYLLSERGYAKLLKILEDDKAWELYDILVDEYFNMREKNQVATD
PMSILKLTFEALEGQQQAIEEIKSDVQDLRENTPLFAIECDEISTAVKRQGVILLGGKQSNAYRNRGLRGK
VYRDIYNQLYREFGVKSHKAIKRCHLNVAVKIVEEYTLPIVLSEBISFVNAQMDFTM

Orf32 (SEQ ID NO:65)

MDQLRVIEGEKVDKPDYVEIYLGAFMNAVNLKKQDEBTRSLSKDITYKKAIFYGVRYISISKNDLNYDYL
MNRFLNISYLENLMKVLTPRDFMTIFPIDKNYDGARYEMKDYFFTMNEIKKIGMDTPIGEKIMEFLWDYQN
FKDITLNLASVSILNKLQKMQGKKTLEEFARLGIDTYTKHKEKGGKEYITNDRGTGEIQEVKKSRRPYL
KPVQ

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Orf33 (SEQ ID NO:67)

MALPRKVHTEFWTDVKVSEDMTPEDKLFMVYLLTNPHTTQLGVYEITPKMIAFEIGLSIESARALLERFEN
HHKLIKYNKLTREIAIKNWGKYNLNRGGKPIEDCLKREIDKVKDLSLIKFI LEHTDHAALKRKINLYAGFD
DTSHDTLAIRDQEEKEQKKEQKEEQEEKEKEKEKQKBEEKEPEEEKTRIKSKASLKSDAKSNPI PYKDIL
DYLNEKANKNFNPKAEGHRKLI RARWNEGYKLEDFFKKVIDNKTQWFGKKSFDGKPLDQFLRPSTLFAQKH
FDNYLNETVNI SNQQHGDQIVIPGFRGEMPF

Orf34 (SEQ ID NO:69)

VKKIQDSFEKLTCLKFADEQCDKHTFNKHGKEVIKLVKRMIDDAGTVYCPRCMVEEQNSVLFQQANNHYKK
INRERKKNVLFQHSIIENQSITESRLSTYKTDQETKENKEKA IKILERIKNGEFLNVYIAGIQGVGKSHL
AYAMLYELVKHYWVISDGEKLNDEHAFKNMKSCLFVEIEKLIRLIQHSFRNIESKYTMDYICISLMVDVDFL
VIDDLGAESGSMNRNGEASDFVHKILYGVTVNGRQGANKTTITTSNLSSAQLFQKYDPKLASRLNGVSKDE
TIVFKTTT DKRIVNLDIGF

Orf35 (SEQ ID NO:71)

MKEVKGKNTKLMEBFDVLLRQLLI KSKTDERVKNFLLDDLFEMLSDNKLQSDIDFKTALNKLREKHFPKFDK
GESKND

Orf36 (SEQ ID NO:73)

MTKEKGQAKEVVNVVRGMSDDDEFIEKYGRLVHHCVWKRYAKKKASIERDTGLDIEDLTQFGMIGLIKARDNF
DLEFGCAFSTYAVPKI IGEIGRAIRDNOKI KVORTVYGVKGKILNQQLADKEPEEIIADILDESVSIVKTA
EYQPSDLSLNKVYASGANEEELT LERMIEDTKTEDIEETTINRAVIREFKAALPPKEYIVLDMRLQNMTOQ
NIANQMGSQVQISRI LAKINQRAAQFGKEGGLQD

Orf37 (SEQ ID NO:75)

LSVTKGVCIDVDHSDLLHEKVEYFLFPAKPSHYVSRFNRKGAHFGCYQAERFQITEKEVWTPPEQP NLPE
LNTSLFYRAQLIWRKKGYKDKPLKDYIVQPRGKHCFYFWDREK KFCGCFPLHWFTDFVPVQSHHIEKTR
EEVKLLQRPDGLAFF

Orf38 (SEQ ID NO:77)

MDIKKLFAMQNILDKRVLSEKNLSRGEVFEFRILAFDELGECKEWRVFKFWSDDRKPRTSIPTGEIIVL
DDGYEVEVYKNPLLEEVVDGLHFAIGLCIDLKTEINFPA SMRCETVTEQFFELYHLAIRLKEEPTAFRADV
LLSHYLGELGELLCSLEEIGHEYIEKNKINHERQSNY

Orf39 (SEQ ID NO:79)

MRVIEISWWAIAIGLYLLIGVALLIWIATDSWGSFLYPVFAVVIVLGLWPLMIRSIVQEISKAIHKWK
RKQKTE

Orf40 (SEQ ID NO:81)

MSGCTIVNVKINKQKRGKMDMKWYNLDSNNEIWTSDKFEMKEEAIQAALKDWTDKMVADRAAVDNEFQI
GQFKQYSPWINADVLLDELYERATDECGEVAEYWL SGVPMDEGEKLQEQINKVVTEWLKGINEHPSFGSI
ENIETIDASKIEYKEN

Orf41 (Fosfomycin resistance gene) (SEQ ID NO:83)

MYQTWKNLLNSIKKILQAKLLVKGKRLAYFDLNLGWIALNVEEDIPRNEIKQSYTHMAFTVTNEALDHLK
EVLIQNDVNILPGRERDERDQRSLYFTDPDGHKFEPTGTQLQNRLEYKEDKKHMTFYI

Orf42 (SEQ ID NO:85)

MIVKATIKLELDDSQKNWVS YVREQGEEAVFHYLEEEVQKKIELADFVEMKYKNK

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Orf43 (SEQ ID NO:87)

MDMSLVGNLKEQKAIDEKVLEFAEEMEIVITKSAASGYSGHRYKIHNENPNRHMMCSKIFIEKLQELLD
GVKVEFKEEKKNILGGSYYEHYIRFKWND

Orf44 (SEQ ID NO:89)

MTNPLLKILFWRKGVERMKTFTNVTTELKIYEAVIEAESAEKIIDVIKHLKRTEDDLVDKGVIINEVSEIN
VSKEQKFE

Orf45 (SEQ ID NO:91)

VNHHLFNWLRDYQKLEEDIAYLEYNLDKTKAELRRWVSGDLREVRLTAESSEGAQVENRIEAEIYELAHKMN
DMYKLKKLISKFRGLENQILKLYVDGMTLEEIAEAVNYSSSHIKKKHAELVRLIKFVEREGVI

Orf46 (SEQ ID NO:93)

MDVQELSRLENLEHKVLQVETKADVLNRTAIQKGDKIKVVYPHLGIQGEYLVKIDNGVLVLAETMCK
IQE

Orf47 (SEQ ID NO:95)

LKKLSKQELAAVMTHCISTLGEQIVNEHINPQKLAQASALHNDLPDNTTPKERREATISLLGKAIDEFLES
KE

Orf48 (SEQ ID NO:97)

MGKGYFNKAVCLVCGHQDRVNHPSKKEYQEVTVCPENGAFVDVWKLKGYKRNTQSNEEPLLITLTDIDA
KPIVHYKGEQIDRKLRTFDWESQSIDKINRTYIHIEHVPADNKRLNTETIQHNHPIANKEQV

Orf49 (SEQ ID NO:99)

MNGFNKIVNDMQNEQVGNAMLDFALAAKMMFAAFTQFKEAGFNEEQSFELTREILIDSLSKNQ

Orf50 (SEQ ID NO:101)

MQVYCSECDKSYDMQPQVTQLPNRIEKCFFICPHCNHEHIAAYVNDKIRKYQADIAKCHERINKKNLAIED
EMKRLRKRFRDRK

Orf51 (SEQ ID NO:103)

MEGQELTLEKKDSIYLRPRYPHKIDASKIKSLKDVIKILGLMDIRLDDKAVIGLEHLIEKEEE

Orf52 (SEQ ID NO:105)

LKRRKNKMANNKLIIEVTADTTEALEGIEVTEAANECADALDKLEKIMDKFTNRSDTVELYCEGKLLSKS
TVNHTADSICRIIKGEELGGSER

Orf53 (SEQ ID NO:107)

MKKPLRPCCEPHCYNLTRERYCEEHRYKEKETQQDKNRYYDRFKRDKESTAFYRSKAWERLREQALMRDKG
LCLHCKNNRKIKVADMVDHIPIKVDPSL
KLKLENLQSLCNPCHNRKTAEDKKKYG

FIGURE 2

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FIGURE 2A: Polynucleotide Sequence of Phage W (SEQ ID NO:2)

CTCAACTTCGCaGaaaaATCCGTTTTTGCATATTTTTTTAAGGGGGTGTAAATCATGGCTGGAAGAAATAAACCAACCACTC
TCTGTTATACAGGGAAAAGGTAGATCAAAATCACATTACAAAAAGTGAGAAAAACAGACGAGAAAAACAAGAAGCAATT
GCGGGGGCATACTGATAAAATGAAGCTCCTTTTATTTGACTGCAGCACAAAAAAGGAATTCGATACTTTAGCTGCTG
AATTAGTCAGATTGAAAAATTTTCAGTAACCTTAGATGTTGACAGTTTAGCAAGGTACGTTGATTCTAAAGACCAATATATA
AAAAATGGTTCTGCTGCTAAGAAAAACAAACCTTCAGATGACTTTAAATTTGTATTCTCAAATGCAAGAAGTAAAAATCT
TTTATTCAATGAATGCCGTTCTTCAGCTAGTGATTTAGGTTTGACCATTACATCCCGCTTAAATTTAGTTATTCCAGAAG
TAGATACTTCACAAACAAAAGCAAAGTGAAGCGCAAAAGCGTTTTTGGTGATCGTATATGAACGGATAATGGAACGGGTTT
TTGCATATTGCGAGGACATTTTAAACGGCAAGATAAAATAGTTGTAAAAAACATCGTTGGGCCATTGAACGATTTATAAGG
GATTATGAGGAGTGTCAAAGTGAAGACAGTCCTTTTTATTTTGATGGAGAGATAGCGGAGGATTTTACTGGTTTGCAAA
GGAATTTAAGCAGCTTGAAGGGATTTTGGCAGGTGAATCCGTAGAAATTAAGTATTTCAATTGTTTCTAGCGGCTAATA
TTTTCGGATTCAAAAAGAAAATAAATGGAGCAAGGCGATTTAGAAAGGTTTTTATTCAGTTAGCGCGTAAAAATGCTAAA
TCTCAGTTTTCTTGC TATTGTAGCAGCTTTTTGTACATTTCTTGGAGACGAAAAACAACGGGCTTATATTGCTGGATGGAC
AAGAGACCAATCATCTGAAGTTTATGAAGCTGTAAAAACAGGGATTAGTTCTAGTGAATTGTTAGAAGGTAAATGGAAG
AGGCTTATAGTACCATTGAAATATTTAAGAATGGTTTCAGTTGTCGTTCCACTTTCAAAGAAGCTAGAAAAACTGGTGAT
GGTAAAAACCGCTCTCTTGGAAATGTGCGATGAATATCATGCACATGAAACTGATGAAATTTATGACGTTTTATCGTCTGG
TATGGTGGCAAGGAAAGAGCCGTTAATGTTTATCATAACAACAGCTGGTTTCGACTTATCAAGACCTTGTATAGAGAGT
ATGAGTATGTCAAGTGACATCTTAGACCCGCTAAAAAATGTAGAAAAACGATGATTATTTCTGTTATGATCTGTGAATTGGAA
AAGAACGATGATATCAAAGATGAGTCGAATTGGATAAAAGCAAACCAATCGTAGCTACATATGAAGAAGGTTTGGAAAGG
TATACGTTTCAGATTTGAAGGTTGCTCTTGATAGACCTGAAAAGATGAGGGCTTTTAAACCAAAAAACATGAATATTTGGG
TCGATAAAAAGGACAACGGATACATGGATATGTCAAATGGCAAAAATGCGAAGTAGATACTTTGATTTTTCAGGTGCG
ACTCTTTGGATAGGTGGCGACTTATCAATGACAACAGATTTAACTAGTGTCGTTGGTTGGGATGGaATGGACGATGAAGGTGA
TTTTATTGTTGGACAACATTCATTATGCTGAAGCACGTTTGAAGAGAAAAGATGGCCATAGATAAGGTGCGTTATGATT
TATGGGCCGAACAAGGGTATTTAACTTTAACGCCCTGGTGAATGGTTGATTATACAATTGTTGAGTCTTGGATAGAAAAAC
TTTTCAAAGACAAAGAAATTCAGAGTTTGATTACGATAAATGGAATGCGTTACATCTAGCACAAAATTTAGAGAAATAA
AGGGTTCGTTTGTGTAGAAATCCCTCAAAGGATTGCTAATTTATCCATTCCGACTAAAAAATTTTCGAGAAAAAGTATACG
AAAAGAAAGTTAAACATAATGGAGATCCAGTCCTTTTTGGGCGCTTAATAATGCTGTTGTTAAATGGATGATCAGGAA
AACATTATGATTTTCGAAAAAATAAGTAAAAATCGTATTTGATCCAGCAGCAGCGGCTTAAATGCAATTTTGTAGGCTAT
GTATGGAGCAAGTGTCAGGTTTGTATGTATCTGAATTTGCAAATAAAGACTTTCTAGGCAAGTTATGGAAC TAGGGAGGGG
GTGAACATGTGAAGATAGTGGATTCTGTTAAAAAGTCTTTAAATTTGAAAAACGCCAACGTCGACGTAATAGAGTTG
AATAAAGACGATGAAAAATTATAGAATGGCTAGGGATTCTCCAGTACTATTAGCGTTAAAGGAAAAAATGCTTTAAA
AGTTGCTACAGTCTTTGCTGTATCAAAATAC TATCTGAATCCGTACAAAGTTACCGTTGAAATTTATCAGGAAGATG
AATATGGAATCCAACGCGGTACAAAGCATTATCTCAACAATTTACTGAGACTAAGGCCTAACCCGTATATGTTCAGTATG
AACTTTTTCCGATCATTAGAAGCTCAAAAAAATTTATATGGCAATAGCTACGCTAACATAGAGTTTGTAGAAAAAGGTAA
AGTCCAAGCGTTATGGCCGATAGATGCTTCTAAAGTGACAGTATACATTGATGACGTTGGTTTTATTAAATTCAAAAC TA
AAATGTGGTATGTAGTAAATACGGGTGGACAACAAAGAGTGTTAAAGCCAGAAGAGATACTGCACCTTTaAAAACGGGAATA
ACTCTTGATGGTCTTGTGCGTGTCTCTACAATGGAATATTTAAAGTCTACATTAGAAAATTCAGCTTCAGCTGATAAAT
CATAAATAATTTTACAAACAAGGTTACAGGTAAGGGATTAGTTCAATATGTGCGGTGATTTAAATGAAGATGCGAAAAA
AGGTTTTCCGAGAAAATTTCAATCAATGTCTAGCGGTCTTCAAAATAGCCATCGTATTGCATTAA TGCCAGTAGGATAT
CAATTTCAACCTATTTTCATTAAATATGTCAGATGCTCAATTTCTCGAAAATACCGAAGCTTACTATTAGGCAAAATCGCTAC
TGCATTCCGGCATTAAATGCATCAATTAATGATTTGAGTAAAGCGACTTTAAATAATATTGAGCAGCAGCAACAACAT
TCTATACCGATACATTACAAGCGACTTTAACAATGTATGAGCAAGAAATGACGTATAAGCTATTTT TAGACAGTGAGTTG
GATAAGGGGTTTTATTCAAATTCATGTAGACGCTATTTTAAAGCGGATATCAAAACGAGATATGAAGCTTACAGAAC
GGGTATTCAAGCGGTTTTCTTTAAACCTAACGAAGCTAGAAGTAAAGAAGATTTACCACCAGAAGCTGGTGGGGATCGTT
TACTTGTTAATGGAATATGTTGCCGATTGATATGGCTGGACAGGCATATTTGAAGGGAGGTGATAC TAATGGAGAAGTC
AGCAAAGAAGGAAATGAAGGAAATTAGAGCTTTGCCAATGACTATTGAAGTCCGTGAAGTTAATGAGGACGAGGGAAAAAC
GAACAATTTCCGGATCGATAAAATATAACAATGAAAGTGCCGAAATGCGTGACTGGTGGGGCGATACTTTCTGTAAGAGAG
ATTGCTGAGGGAGCTTTTGATGAAAGTTTAAAGTTTCGTGATGTTGTAGTTTTATGGTCTCACGCACATCTCAAGTATT
AgGAAATACTAAAAGTAAAACTTTACGAATCGAAAATGACaAGAAAGAATTACGATTTGAATTAGATATTCCTAATACAA
CTGTTGGGAATGACGCATGGGAATTAATTAAGCGTGAGATGTTGATGGAGTTTCTTTTGGGATGAAGGTTACAAAAGAC
AAATGGTCAATCGAAGAACGTGAAAATGGAAGCTTTATAAGCGTTTCGATTTTAAATGCTGAAC TATATGAAATATCACC
GGTTGCATTCCCTGCATATCCAACGAATGAAGTGAAGTGACGTTTATTGGATGATTTTAAAGCTGGAGAAAAGCGAGTAG
CTGATGAGTTTAGGAAAAGAAAAC TACAAAATCGAACTAGAGCTTATATAAGGCTCTTTTTTTATTGATAAAATTTAAGGAG
TGATTTGAATGTCAAAAGAATTACGTGAATTATTAGCTAAGTTAGAAGGGAAAAAGGAAGAAGTACGCTCTCTTATGGGA
GAAGATAAAGTGGCAGAAGCAGAACAAATGATGGAAGAAGTGCGATCACTTCAGAAAAAATTTGATTTACAACGCTCATT
AGATGAAGCAGAAACGGAGAACGAAATAATGGAAGAGAAGTTGAAACACGTAATGTAGATGGTGAATGGAATACCGCG

FIGURE 2

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ATGTGTTTATGAAAGCATTACGCAATAAACCATTAATGCTGAAGAACGTGAATTTCTTGAGGATGATTTAGAACAACGT
GCCATGTCAGGATTAACCTGGGGAAGATGGAGGACTGTGCATCCCTCAAGATATTCAAACGCAAAATCAATGAATTAGCTCG
TTCATTTGATGCGCTTGAGCAATATGTAACGTGTTGAACACAGTGCCTACACGTTTCAGGATCACGAGTATTAGAGAAAAATT
CAGATATGATTCGGTTTGGCTGAAATCACTGAAATGGGTGAAATTCAGAAACTGATAATCCGAAATTTTCAAATGTACAA
TATGCAGTGAAGGACAGAGCAGGTATTTTACCGTTATCTCGTTTACTTCAAGATAGTGATCAAAACATCCTAAAGTA
TGTGACTAAATGGCTAGGTAAGAAATCTAAAGTTACACGTAATGTGTTAATCTTGGGCGTAATTGAAAAGTTAACAAAAC
AAGCAATCAAATCTCTGGATGATATTAAAGATGTATTAAATGTTAAATTAGACCCAGCGATTCTCCGAATGCGATTTTA
CTTACAAACCAAGA TGGATTAAATTTTAGACAAATTAAGAATAAAGACGGAATAATATTTTACAGTCAGATCCAAAC
GCAAAAAACAAAAAATAATTTGCTGGTACTAATCCAGTCGTTGTTTTCGAATCGTTTCTTAAAAATCAAAGGGAACCTA
CAGCTAAAAAAGCGCCACTTATTATTGGTGATTTAAAAAGAAGCTATTGTTTTTAAACGTGAAGATATGGAAC TGCT
TCTACAGATGTAGGTGGTAAAGCATTCACTCGTAATACATTAGATTTACGCGCAATTCAACGTGATGATGTGCAAAATGTG
GGATAATGAAGCAGCAGTTTACGGAGAAATCGATTTAAGCGCTCCTGTTGAACAACCTCAAGGGTAAACTAAGGAGGCAT
TTGAATGCTTGTACCTTAGAAGAAGCTAAAGAATGGATTTCGAGTGGACGGAGACGATGACCCAACTATCACTATGTTAA
TTAAAGCGGCTGAATTATATATTTA CAAAGCAACTGGCAAAACATTTACTCAAACAAATGAAGATGCTAAGTTGCTTTGT
TTATTTCTGGTGGCTGATTGGTACGGAATCGACTACTTGTAGGTGAAAAAGCCAGTGAAAAATCAGAACCATTTGTTCA
GAGTATGATATTACAGCTCCAATATGCTTCAGAGCCTCAGGAGGAAAGAAAATGAATCCTGCAAAATTAGATAAACGGCT
TACATTTCAAGTAAAAGATGAAAATGCAAAAGGCGCTGACGGTGATCCGATAGATGGATATAAAGATGCTTTTACCGTAT
GGGCTCTTTTGTATTTTAAAGGGAAGGAAATACTTTGAGGACGACAGCTGCTAATAGTGAGGTTCAAGGAGAAACAGAA
ATCAGAAAATCGGGATGATGTAAGTGCAGATATGAAAATTAAGTACAAAAACGTGATTTATGATATGTTTCCGTTATTCC
AACTCAAGATCATACTTTATTAATCATGTGGAACCGTGGTGAATGaATGGCTGATGGTaTAGATTTAGATTTATTAGGA
TTTGATCGTTTAGTTACTGAATTAGACCAAATGGGGTTACGGGAGAGAAAAATGAAGATAAAGCTCTTGACGCTGGTGG
TGAACCTATTCGTAAAGCCATTGCAGAACGAGCGCAAGAAGCCCAAGCCCCAAAAACGATCTAAAAGTGAACCGTGCG
GTACAGGGCAACATGGTGCAGACCAGATAAAAGTAACAAAAGCTAAACTTGAAGGTGGAATAAAAAACAGTAAAAATAGGT
CTTAATAAAGCCGATCGTTCCCGTGGTTCTATTAAAGTTCCATGAATGGGGTACATCCAAAATGCCAGCACATCCATT
TATAGAGCCGGTTTAAATGCTTCAAAAGCGGAAGCTGTACGTGCTATGACAGATATTTTAAAGAACGAAATGAGGTTGG
ATTTGTGATAAATTTAAGACCTGATATTTTACAGCTCTTGAGATGATCAAGAGCTTGTTCATTGTTGGGTGGGAAC
GAATTTATTACCGTAAAGCAAAGAAGGCAGAAGAGTTTCCGCGAATTACGTATTTGAATTAGACAATAGGCCAGATGGA
TTTGACAGATAATCAAGAGATTGAAAGTGAATCTGTTTCAAGTTGATGTTTGGGCAAAGAGTAGTACAACAGCAATCCA
TCAAAAAGTGAATGAATCATGAAAAGAAATGGTTTCTCAGCTATGCGGTTGCTGATTTATGAAAGGATACACAAA
TATTTTATTATGCGATGAGATTTCGCAAAAGGAGTGGAATTATAAATGGCTGGAGAAGTTGTAAGAATTAGTTCAACGGTT
GGTGTAGACAACCTTGTATATGCGAAAGTTTTACAAGATGATTCTGCTGCTATTAAATATACAGATGTAAAGAAAATGGA
AGGTGCTGTAAAGGTTAAATTAACATAAAAAAGTAGCTTCTGAGGTTATGTGGAGCGATAACAGAAAAATCAGAGATTGCAG
AATCTGATGGCGAAACTGAAGTGGAGATTGAGGTTCCGAGGACTTTCACCTTCTACAAAAGGTGACATTTGAAGGTTTCCA
GAAGTAAAAGATGGCGTTTTAGATGAGAAACGTGAAGGTGAGAAACCATATTTAGCTATTGGTTTCCGATTCTTAAAGC
TAATGATAAGTATCGATATGTTTGGTTATTAAAAGGGAACCTTTCACAAGAGGAAGAAGAAGCTGAAACGAAAAAGACA
AACCGAACTTCCAAACAAACAAAATGAAAGGTTCTTTATTGAACGTGATTTTGATGATAGAACGAAATTTACAGCAGAT
GAAGATGAACCAACGTTCAAAAATAGTTGGAGATAATTGGTTTAATAAAGTATATGAAAAACCAAGTGACACAACCCACC
AGCAGAAAGTAAAGAGGGAGCAAAAGCTCTCTCTTTTATTAAATTTAGGAGGGAAGAACTATGAAATTAACATTAATG
ATTAATAAAGAAAAACAACTTTTAAATATGCCAGAATTTATTCAGCCCGCTTATTCGTACGGCTCCTGAACCTTGCTGA
AATTCCAAACAATCTGGTCCAGAAGATATGGATAAAATGGTTCAATTCTGATGAAAGTTTATGATGGTCAATTTACAT
TAGATCAGTATTGGGATGGTGTGATGCCCGTAAATCTTATCGACAACCTCAGATGTAATTAACGCAATTATAAATGAA
ACAGTGAAGCAGCAGGGGGTAGTACTGAATCAGGAGAAGAAGAAAAACCAACGCATAGAGGGAGGAGGGCTAACGTTT
AGTGAGTTTATGGACGAGCTCTACCTCTCTTTTATTGCGACAAGGGTACAAACACCATCAATTGATAATGAGATGGATAT
TTGGCATTATTGAGACTTAATCGAAAAATGCATGAAAACGGAATGAAAATTACGAAGGCTCCAATTCAAATGAAATAG
AAGTGCCAGCGGAAAAACATTATTAAACGAGGGAGGTGAGACTATGGCGAATGAAATAAATACTAGTCGTTAGACTTTC
CCTTGATAACGTAAATTTTACAGACAAGGTATCTCGAATTCAGGTCGTGCAGTCAGGACGTTACAGAATGAATTGAAATCTG
TAAGTACAGGAATGGGCGGTTTTGCTAACGCTAGTCAGCAACACAAGCGAAAAATGAATACACTCAGTAGGCTCATTTGAT
GCGCAAAAGAGAAAATTAAGCGTTACGACAAGCCTATGATCAAAATAAGGCTAAATTAGGTGAAAATGATGCAGCAAC
CCAGCGAATGCTTTCGCAAGTTAATAAGGCAGTTGCTGATTTAAATAGATTTTGAATAATGAATTAAGCAAGTAAACCGT
AAGCTGAACAAAAAGGGATGGATAAGTTAAACAACCTCTTTAAATCCCTACAAGCTGAATTTTCACTATTACAAACAGGT
ATGGGCGGTTTTTCTAATGCGACAGAACAACAAAGGGCTAAAGTAGATGTTTTTATCCCGTATGGTAGATAAACAAAAAGA
GAAGATTAGGGAACCTTCAACAAGCCTATAATCGTGCTAAAACAGAAGAAGCGGAAGCGAGTCAATCAGCACAAAGATACG
CTGAACAAATTCATCGGGCAACAGCTGAACCTGAATCGATTGAACTGGATTACAGCAGTCAAACTCGTGAATTAGAACAG
CAAGGGAATCGCCTATTGAACCTTCGGAATCGCATGGAGACATTAGGTAATCAATTTGCAAAATGCCGAATGCGATCGG
CATGGTATTGGTGGTATGACTTACGCAATAGGTGGGGCTTAAATCAGCAATCACTGAATCAATGAATTTTGGAGCAAC
AGATGGCCAATGTAAAGCTGTTTCTGGATCTACTGGAGCAGAAATGAAAAAGTTAAGTGAATTGGCTGTTAATATGGGA
GAAACAACAAAATACTCCAGTGTTCAAGCAGGTCAAGGTATCGAGGAATTAATAAAGGCTGGTGTTAGCTTACAAGATAT

FIGURE 2

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TATTAACGGCGGATTGGCAGGTGCCCTTAACTTAGCGACGGCAGGGGAATTAGAGTTAGGTGAAGCAGCCGAAATTGCTT
CCACAGCTCTGAATGCATTTAAAGCAGACCATTCTTTCAGTTGCGGATGCAGCCAAATATTTTATCTGGTGCAGCCAAATGCT
TCCGCAACTGATGTAAGAGAGTTAAAAATATGGACTTTCAGCTTCATCAGCAGTAGCAGCGGGAGCCGGAATGACGTTTAA
GGATACAGCTACAACCTTTAGCGGTATTTGCAACAAAATGGTCTTAAGGGATCAGATGCAGGTACATCTTTAAAAACAATGT
TAATGAGGTTAAATCCTTCAACAAAAGAAGCATATAACAAAATGAGAGATTTAGGACTTATTACTTATAATGCACAGGCA
GGTTTTGATTTCTTAGTTAAAAACGGTATTCACCAGCTTCCAGAAATGTAGGGGATATAGAAGTAGCTTTAGAACAATA
TGTAATGAAAAACAGAAGGTGTAACGAAATGGAATGATAAATGTGATACAACGTTTCGCGAATTAGCAACAAGTTCGGCAT
TTTTATCATCAAAATCTATGATCAACAGGGGCATATTCAGTCTAGAAAATATTTTCAGGTACACTTCATGAATCGATG
AAAGATTTAACAGACCAACACGAAGTATGGCTCTGGAACCATTTATTTGGTTCCGATGCTGTACGTGGTGCGACTATCTT
GTTTAAAGAAGGCGCCAAAGGTGTCAATGAAATGTGGGATTCATGTCAAAGGTTACAGCAGCTGATGTAGCAGCGACCA
AAATTGATACCTTTAAAGGGAGACTTACATTACTAGATTTCAGCGTTTTCACAATGAAAAAGACAATGCTGTATGCACTA
GCTCCAGTAGTTAGTGTTTTTGTGCTGGTTTACAAAACTTGTGTGATGGATTCAACTCTTTACCTGGACCAGTACAAAA
GGCAATAGCAATTACAGGTGGTATCGTCTTGTCTTAAACAGCTGTGGCTACAGCAATAGGTGTGGTTTTAGCAGCGTTTTG
GAATGATTGCTTCAGGAATTTGGTTCTTTATCTTTGCTTTAGCATCAGTCCGTTGGGATTGCTGGAATGCGGCTGGAGCA
GTTGGATTCTTAGGAAGCGCGCTTGGCGTTTTAACAGGGCCAATTTGGTCTAGTAGCAGCGGCTCTTATCGGAATGCTGT
TGTTGCATATAAAGCATATCAAAAAGCGACTGAAGACAGTATCGCATCAGTAGACCGCTTGTCTACAAATACAGAAGGGA
AAGTAAGCTCCTCAACAAAGAAGGTTCTTGGCGAGTATTTCAAGCTGTCCGATGGTATTAGACAAAAGTTAACTGAAATT
AGATTGAACCATAGCAATAACAGAAGAAGCTCGCAAAAGTTGATTGGTCAATATGACAAATTAGCTAATACAATCAT
TGAAAAAACCAAGCAAGGAGCAAAAAGAAATTTGAAGGGCTTAAAAAGTTCTTTGCTGATTCTGTATGATTAACCGCTG
AAGAAGAGAACAACGAATCGAACAGTTAAATCAGCACTATGAACAAGAAAAGCTAAAAACGCAAGAAAAAGAAAATAAA
ATTAAGAGATCTTACAAACAGCGGCTAGAGAAAACAGAGAAATTAACGACATCCGAACGTATCTCTTACAAAGCATTGCA
GGATGAAATGGACAGAGTTGCTGTTGAGCATATGTCTAAAAATCAAATGGAGCAGAAAGGTTATTTCTGAAAAATATGCGTG
TGCAGGCTAGTGAAGTTTTCAGCTAGACAGGCGAGCGAGGTTGTAGAGAAATAGCGCCAAAGCAAGAGATAAAGTTATTGAA
GATGCGAAAAAGACCCGTGATGAAAAAATTCAGAGGCGATTTCGCCAACGTGATGAAAAATAAACCAATCACTGCTGATGA
AGCGAACGCAATCATTGCAGAGGCAAAACGTCAATATGATAGTACAGTTTCTACAGCTCGAGATAAACATAAAGAAATTG
TGAGTGAAGCAAAAGCGCAAGCTGGTGAACATGCAAAATCAGGTAGATTGGGAAACTGGCCAAGTAAATCGAAATATCAA
GCTATGAAAGACGATGTTATTCGAAAAATGAAAGAAATGTGGTCCGACGTTACCAACAAATATGAAGATATGAAAACTC
TGCAAGCAACAAAGTAGAGGAGATAAAAAATACAGTTTCAAGAAAATTTGAAGAGCAGAAAAAGCTGTTACTGATAAGA
TGTCAGAAATAAAAAAGTAGTATTGAAGATAAGTGAATACAGTTGAAAAGTTTTCAGTTCTATAAATTTACGTTCCATC
GGTAAATCAATCATAGAAGGGCTTGGCAAGGGAATAGATGACGCTTCAGGAGGCTGTTTTAGTAAGGCTGCGGAAATTC
AAGTGATATTAAAGAGACTATTTCTGGAGCATTAGAAATTAACAGTCCGTCTAAAGTGATGATTCCAGTCCGTAGCGCAG
TTCCAGAAGGTGTTGGGTTGGTATGGATAAGGGAAAAACGATTGTTGTGGATGCAGCAAAAAATGTAGTCCGAACTGTT
AAGAAACAAATGGGGAATATGCCATCTGTTTTGATTTTGGATTCCAAACAAATCAATATAGTATCCCGCAAAATACAT
TAGCGATTTTCAGTGGATATATGCAACCGCAATTATCTTATAACAATCCATCTATGGCAAAAAACAATATTCCCAATAGAC
CAGGTGGAGAACAAAGACTGAATTTAACCCTAAACATGACTAATGTTTTAGATGGAAGAGCTTGCAACCGGAAGTTAC
ACCTATACTACAAAACCTCAAAATCGTGAACAAAAAAGAGAGCGGAATTTTAAGGGTGGTGAGCACGTTGGGGAACTT
AGTTTTACTTTTTAATAATATTAGAAAAGATTATATTCAAATGCTAGTTGGAAGAAAACGTCCTTCATGGGCTCCAGTAAA
AAGAAGATTAGTAAGAGTCCCTCATCGCGCAGGGGCTTTTACTTAATACAGAAACGAGGAAACGTCGTATTGACGTTT
CTCTTGTTATTAAAGCGAAAAAAGATATGGCAGATTTACAAAAGTTAAAGAAAGATTAGCGGATTGGTTATATACAGAG
CAACCTGCTGAACCTATTTTGTATGATGAGTTAGACAGGACTTATTTATCATTAAATTGATGGTTCTGTGCTGATTGGACGA
AATAGTCAATAGAGGTAAAGGTGTTATTACTTTTGTGTTGTCCAAATGCCGTATAAATTAGGGAAAAATCAATACTCACAAAT
TTACGCAAGAGTGGTCTACAGAAACAACCTTCTTATTTACTAATAAAGGAAGTGTAAGAAGCTCCAGCATTAATTGAAATG
ACAGTGAAAAAACCAAGTACCTTTTTAGATGTATGGTTTGGAGAGTATCCGCATAATCGTGATTATTTTCAGAAATAGGCTA
CCCTCTGACTGTGGAAGAAACACGGTACAGAACGAGAAAGAGTCAATGTGGGATGAAATGGCTACTCCTATAGGATGGA
CACCTGTTACTGGACAATTCGAGGAGATGAAAGGGACAGGTAGTTTTAAATCAAGAGGTGGTCAATGCACTATATTGTGAA
GATTACGGAAAAAGAGACAGGATTCTACGGTGCTATAGCCAAGAAAAACATTCCGGGCGGCCCATTAACAAGACTTCGAAAT
GGAGGCATGGGTGACTTTAAAGTCCAAAAACATAAGCGAAATGGGACGTGTTGAAGTTCTTCTTTTATGATGAGACGAGTA
ACGTGATATCCCGCATCAATATGAATGATCTATATGCGACCGCTGAAATTACAAGGGCGCATATGACAATTGGAATAGC
GGAACACCCCAATAGTTTTTCGAAAATTAGTTGATACAAGTGGATTTTATTCGACAACATTTAACCAATTCAGAGGGCGTTT
ACGTATTGCTAGGCGGGGAAGGTGTGGTCTGTATATGTGGCTAAATTTATAGATGGTACAGAAAAAGATGGAGCTTCAC
TTGTAGAACGTTGGATTGATGAAACAGGAAATCCGATGACAGAACGTAAAAATGCAACAAGTTATGATTGCGATTGCAAG
TGGGATAATCATCAACCTATTAAACGAAATGCAAAATGATGATTTAAAAATTTGGAAGGTAACAAAAGTTTCATCTAATGC
ACAACCATATCTTTGATACCTGGAGATAAAATGTTTATCGATACGATAGAAAAAGTCTTGTACGATCAATGGGGAGAAAG
CAATCAATATAAAAGAAATCTTTAGTAATTTTCTGTGCTAATACGTGGTGAAAAATCGTATCGATATTATGCGCGCTGAT
GTAAACGCAACCAATCAGTTATAGGGAGAGATATAGATGAGAACCAAGCGGGATTTTGCATGTTGTGGATTTTAAAAACA
GATCAATCTGTCGAGCTATCCAACAGAGGACTATTGGGATGACAAACGGCATTGGGAACCTAAAAATAATGTTGACAT
GTTGGATTTTACCAGCATTTGATGGAACAGACCATGCAGTTACCTTACAACAACAGAAATCTTGTTTTGAAAAGAAGTTCCGGC

FIGURE 2

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ATGGAAGAATCGTACCATATGTTATTACAGAGACTGAAAAAATTCGATACACGATCTATTACACATATGCTTCAGGA
GCTTGGATTCAAATTCGGAATCAGGGATTATAAAACCACAACGGATAGAGAGTAAGACGGTTAATGAGTTTATGGATTT
AGCACTCTTAGGTATGAAGTGGAAACGCGGAATTACTGAATATGCTGGATTTCATACAATGACCATCGATGAATATATTG
ACCCACTCACTTTTTTAAAGAAGATTGCATCTTTATTTAACTGGAAATTCGATATCGTGTGAGATTAAAGGTTCAAGA
ATCATCGGTTGGTATGTAGATATGATTCAAAAACGTGGTCAATGATACAGGCAAAAGAAATAGAATTAGGAAAAGATTTAGT
CGGTGTACGCGAATTGAACATACACGTAATATTTGCTCTGCTTTAGTTGGATTGTAAAAGGTGAAGGTGACAAAAGTAA
TCACTATTGAAAGCAATTAATAAAGGTCTACCCTATATCGTAGATGCAGATGCGTTTCAAAGATGGAATGAACACGGACAA
CATAAATTCGGTTTTTATACACCAGAAACAGAAGAATTAGACATGACTCCAAAACGTTTACTGACGCTTATGGAATAGA
ATTGAAAAAGCGTGTCAACTCTTCAATTTCTTATGAAGTGAAGCACAACTATTGGTCGTATTTTCGGTCTAGAACACG
AATTAATTAACGAAGCGACACGATTAAAAATTAAGATACAGGGTTTACACCAGAATTATATCTTGAAGCGCGAGTAATA
GCTGGGGATGAATCTTTACAGATTCAACGCAAGATAAATATGAATTCCGGAGATTATCGTGAGATAGTTAATCAAAATGA
GGAATTAAGAAAAATTTATAATAGAATCCTTAGTTCGCTTGGTAATAAACAGAAATGATAGATCAGCTAGACAGATTAG
TTCAAGAAGCTAACGAACCGCTAGTAATGCAAGAAGGAGTCAGAAGCAGCAAAAACACTAGCTGAAAAAGTACAAGAA
AATATTAAAAATAATACCGTTGAAATTATAGAATCTAAGAATCCACGACAACAGGTCTTAAACCATTTAAACCGCTTTG
GCGTGATATTAGTATCGGAAAGCCTGGTATTTTAAAAATATGCACAGGTACAGCGTGGGAATCGGTGTACCTGATGTTG
AATCTGTAAAAAAGAAACATTAGATCAGGTTAATAAAGATATCGCAACCACAAAAACAGAGTTAAATCAAAAGGTTCAA
GAAGCCAGAACC AAGCGACTGGTCAATTC AATGAAGTGAAGAGAGTTTACAAGGCGTTAGTCTGACGATTTCTAATGT
TGAGAACAAACAAGGTGAAATCGATAAGAAGATTACTAAGTTTGAACAAGATTCAAGTGGATTTAAACCTTCAATTGAAT
CGTTAAGCAAAAAAGATACTGAAATTAGTAATAAATTAATACAGTTGAGTCTACTGTGGAAGGTACGAAAAAGACGATA
TCTGAGGTACAGCAAACTAATGATTTAAAGAAAAAACTACTGAAATAGAAGAGAAGGCTGGAAAAATCACCAGAAAA
ACTTACAAGTTTAGAGACAAGAGAAGTTAATGTTTCGAAACTATGTAATTAAC TCTGATTTTTCGAATGTTACAAATCTTT
GGATTGGAATTACTAATGCAACTCTTTTTAAATTTGTAGATGTGAATATTTTCCGAAGCCTCCGCTATTAAGAAAGGTTTA
CAAATAACAAGTAATAAAGCTTTTGTATTATCAGAAGTTACCCGACAGCGTGTTTAAAAAGAAGAAGGGGATAGCTTCTTG
TTATATAAATGATTCAAGTTTACACCTGGTACAGATTATCCAGCTTTATATATGAGATTCACTATGACCAAAACGGAA
CAGAAAAACAATATTATGTCATTTTAAACAACAAGAAGTAACTAATGGATGGATTAGGATTTCTATACCATTGATACA
ACTGGATATACAGGTGAATTAAGAAGTACGTGTAAATATAGTACCCTGACACAACACTACTATCGATGCAACGTTTCAC
TGGAATAATGGTTACATTGCGGTGACTTAATGAATCTTGGAACTCTCGCTCCAGAAGATGGAGTAACACAAGGTGTTTTC
AATCTAAAAACAACCGAGATTGAAAAAAGTGTGGATGGTGTAAAAACTACTGTAAACAAATGTTCAAAATAGC CAAGCTGGA
TTTGAAAGCGCATGTCTAATGTGGAACAAACAGCAACTGGATTATCTTCTACCGTAAGTAATTTAAACAATGTAGTATC
CGATCAAGGAAAAAAGCTTACTGAAGCAAAATACAAAACCTGAAACAGCAAGCAACCGCGATTGGAGCAAAAGTTGAGCTTA
AACAAGTAGAGGATTATGTTGCTGGGTTTAAAGATTCCTGAGTTGAAACAAACAGTTGATAAAAAATAACAAGATTTATTA
GATGAATTAGCCAATAAGCTTGCAACTGAACAATTTAACCAGAAGATGACTCTGATTGATAACCGTTTCACTATTATATGA
ACAGGGTATCAATGCCGACGCAAAAAAGACAGAAGTATATACAAAGACGCAAGCAGATGGACAAATTTGCTACAGATTCCTT
ATGTAAGAGATATGGAGTCCGCGCTGCAGCTAACAGAAAAAGGTTAGCATATCTGTAAAAAGAAAATGATGTAATCGCA
GCCATTAAACATGAGTAAGAAAAACATTAAGTTAAATGCTGCACGAATAGATTTAGTTGGTAAAGTTAATGCGGAGTGGAT
TAAAGCTGGATTGCTGAGCGGTTGCCAAATTAGAACATCAAAATACGGATAACTATGTTAGTTTAGATGATCAATTTATAC
GTCTCTATGAAAGAGGAGTTGCTAGAGCATTTC TGGGGCATTACAGAAGATCAGATGGTGCAGTACAACCGACTTTCATC
TTAGGTTTCAGATGAAAAGACTAACGCTCCGGAAGGTACTTTGTTTATGCTCAAGCAGGTGCAGGATGGTCAGGGGCTTA
TGCGAGCATTTGGTATTAGCAATGGCATAGTTGATGGTGCAGTCCAAAAGTCTGTGTATTGGGAGTTGCAAAAGAAACGGAC
TAAGTGTCTTAAACGCTAATGATTACCATGTTTTTTACGCTGGAAATGGAAATTTGGTATTTTCAGAAGAGGGGAAACAGGG
TTGTATCAAACTTCGTTAGTCGTTGAAGATAATAGTACAGATTCGATTTAAGATTACCTAATGTAACTATACGTAATAG
CCGTGCAGCAGGATATACAGGAGTTATTCAAATTGAAATCCCTGTTACTCAAAATGGATGGGGTGCTGTTCAAGGGAATT
TTATGACTCCTTCATTACGGGAGTATAAATCTAATATCCGTGATATTTCTTTTCCGCCTTAGAAAAAATTAGAAGTCTT
AAAATTAGACAATTTAATTATAAGAAATGCTGTAAACGAACATATACGGATGAGAGAAGAGAAAAGTCCC AATGATCCACC
ATTGACAACAGAAGATATTAAACATACTACGGTTAATCGTAGATGAATGTGATGAAATGTTTGTGGATGAAAGTGGGA
AAGGAATTCATTTGTACTCATACGCATCCATTGGAATTAAGGTTTACAAGAAGTTGATGCAACAGTACAGGAACAGGAG
GTAGAAATAGCAAATCTAAAAATCACAAATAGCTAGTCAAGAAGATCGGATAGCACGATTAGAAGAAATTATTACTACAACA
ATTAATAAATAAGAAACCAGAGCAGCCATAGGCTGGTCTTTTTATTTTGGCCAAAAAGGAGAGGAAAAAGATGGATCGTAT
TGATGTATTACTAAAAGCATTATAGCTGCGTTTGGTGGCTTGTGGGtATTTCTTGGGAGGATGGGATGCAACATTGA
AAATCTTAGTGACAATGGTAGTTATTGATTATTTAACTGGCATGATTGCAGCAGGATATAACGGAGAATTAAGAGCAAA
GTTGGTTTTCAAAGGCATCGCCAAAAAGGTGGTGCTTTTTCTTTTGGTCCGAGCGCGCTCAACTAGACTCGGCACTTGG
AAGCAACAGTGCATCCGTGAAGCAACAATTTCTTCTTCATGGGTAAATGAATTACTTTCACTCTTAGAAAAATGCCGGC
GAATGGGTATTCCACTCCCACAAGCATTAACAAATGCAATGTAGATTTTAGGTGGTAAACAAAAACAAGAAGAGAAAAAA
GGAGATGTTTCAGTAATGGAAATCCAAAAAATTTAGTGTGATCCAAAGTAAAGTATGGTACAAAGTGTCCGTATCAATGAAG
CCTAAATATATCACTGTTTCAACACATATAATGATGCTCCAGCTGAAAAATGAAGTGAGTTACATGATTAGTAACAATAA
TGAGGTGTCGTTTTCATATTGCAGTAGATGACAAGAAAGCGATTCAAGGTATTCGCTTGGAACGTAATGCATGGGCTTGGC
GAGACGGCAATGGTTCCGGGAATCGTCAATCCATTCTGTAGAAATCTGTTATTCAAAATCAGGAGGAGATAGATACTAT

FIGURE 2

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AAAGCTGAGGATAATGCTGTTGATGTTGTACGACAACCTTATGTCTATGTACAATATTCGGATTGAAAATGTTTCAACTCA
TCAATCCTGGTCAGGTAATATTGTCCGCATAGAATGTTAGCTGAGGGAAGGTGGGGAGCATTTCATTGAGAGGTTAAGA
ATGGGAAATGTGGCGACTACTTCACCAACAAAAACAAACATCATCCAATCAGGGGCTTTCTCACCGTATGAAACCCCTGAT
GTTATGGGAGCATTAAACGTCACTTAAAAAGCAGCTGATTTTATCTTACAATCGGATGGATTAACTTATTTTATTTCCAA
ACCGACTTCAGATGCACAACTAAAAGCAATGAAAGAATACCTTGACCGTAAAGGTTGGTGGTATGAAGTTAAATAAAACA
AAAGAATAGTTTATGAACAAAAATAAGAGCCGTCTGTTGGGCGGCTTTTATTTATGCTCAATTACTGTTGCACTAAT
TTTAGGCATTCCTGTTTTATCTTTTTCTGTCGTAGGCGCCATAGATTGTTACTATTGATCCTTTAGATATTTTTAATCCGT
TTTTAAGTGTATTTCATTTTCGTTTCGTTTGCACTCCACTTTGGACAATTTGAATAGTGTACATGCCTTTGCCGTCATTT
TCGTTTGTGCTTATGACAAATGAAGGTAATGCTGAAGACTTAAGTAATAAATCTACCGTTCCGGTAGCTTTAAGCCTTTT
TCCTTTTTCTGATTGATCTCCATTTGCTTAAACAAACTAACTTCTTCAGCATCTTGCTTTATCTTCTTATTTAACTCAT
CCTGAGATGTTAAATCTTTTTTAGTTTTCTGGTTGAGATTTGACGTTCTGTTTTTCACTTGATTCACTTTGTTTGAAGAA
TCACAAGCTGTTAGACCTAACAATAAGGTACTTCCAATGCAAAATACTTATAAGTTTTTTATACATTTTCATTCCTCTCT
CTATCCAAATTTCTTCCATGTGCAATTTTAAATCCTTTGCAATTTTATAGGCTGTAAGAAAGGTAGGTAGCGTCGTGTTA
TTAACGAGTGAACTCATTTAGTTTGTACTAATTTCCAATAAGTTTGAAGAACTCCTTTTGACGTATTTCTCTTCAGCAAA
AATAACACGAAGTTTACATTTTAAATCGCACAAATATCACCTCTTAAATTATATACAATTCGCATATGGAAATGTGTCCTCC
TTTAATTTAATCAACGAACATTTAGAAAAGTTTAAATGGACAGGCAATATAACTCTTTCTAAGTCATATACCTATATCAA
GACCACGAGGAATACCAAGTGGAACATAAGGACATCAAGAGGGGAGAGGATTACATGCGTTGGCAGTATAATCACTTGAAT
ACAACCTCCATATCTTCATCCATCCAAAGAATTATGTTCAATGTACAATGGATCGAGATCAAGAGCAGAGACGGAATCAAT
TTTAAATCACATGAAAAATCATGAAGTTTATGATCGAAAAAGATATAAAGGATATTTCAAGTTGTACAGGTTATTAGAAG
AAGATCTATATGGAGAGGAAGAAGATGTTTTAAACTGGGAAATTTCTAATGGATTGTTATGATGTAGTTCTTACAAGAAAA
GGTATTGCATTTCTGTAAGAAAGAGAGGAGGAAACAGCATGACTCTTGCTGGAGAAGCGATTATTTTGGACGGCAACA
GGGTTGTCTAGTTGCAATGAAGGCAGCAGAAAAAATGGGGAAAAAGTGTCCACATTGGCTTCCACGTGTCACTTTGTA
CACAACACTTCACAGGCTCGTTTCTATACCTTCTACGTTATGTTCTCGTTTTATTTCTATGAAGGAATACGATGTGGAAAC
TTTTCAATCTCTTATGTCTATAAGGAGTTTAGCTTGTATGCACTGATTTCTTGAAGACAGGATATACCTCTATAGAGG
GATATAAGGAGTGATTTTATGCTGGAGTTGTTATCAGTACCATTTCGAGGTTTAAATTTTCGCCATAGTTGGCGAAAGGCT
CAAAGGAAGAGAGAGTGATCGAAAGAAAAATACAAGTTTTTTTTTGAAGTAAGCGGAATTGCGATACGTAGAGAGGACAAAT
TACAGTATCCAGTTTTTCTTGAACAAAAAGAGGATGACCGAAGTACAACCTTATATATATCGGTTGCCTGTAGGAATGCCG
AGTAAAAATTATTCAGAAGGTGAGGATGTTGTCTCTGAAGGGCTAAGTAAACCTGTCCGAATTGATTATGATAATTACAA
GCTAAATATTCTGTGTGTTTTCAAGGGATATACCGAAAAAATGGTCTAGGTTCTAAAGGTTTGGTTGAGAGGAAGCTGGT
GTGTTCCAATGGGCCAAAGTTTAGAAAACTTATCTATCATGATTTTGATAAAACACCACATATGACACTAGGTGGTCTG
ACACGGATGGGAAAAACGGTATTTTTTAAAAAATGTAGTTACTTCTTACTTTAGCACAACCAGAACATATTAATTTATA
CATTATTGATTTTAAAGGGGGCTTGGAGTTTGGGCCGTATAAGAAATTTAAACAGGTAGTTTCTATTGCTGAAAAGCCCC
CAGAAGCTTTTATGATATTAACATACTCTCAAGAGATGGAAGAAAAATGGAATATATGAAATGTAGACATTATACG
AATGTTGTAGAAAACAAATATCAAGAGCGTTACTTCAATAGTAGACGAAGGAGCCGAACTTTGCCAGATAAAAGTAT
GAAAAAAGAACAGCAAAGGTTATTAGGAGCGTGTCAACAAATGCTCTCTCATATAGCGCGCATAGGTGGTGTCTTTAGGT
TTAGATTGATTTTTTGTACACAGTACCCGACAGGGGATACATTACCGCGCCAAAGTAAAAACAAATAGTGATGCGAAATTA
GGCTTTAGATTACCGACTCAAACAGCATCAAGTGTGTTATAGATGAAGCGGGATTAGAAACGATAAAAAGCATTCCCGG
ACGCGCGATTTTCAAAACCGATAGACTTACAGAAATACAAGTGCCTTACATTAGTAATGAGATGATGTGGGAGCATTTAA
AAGGATATGAGGTGGAGAAACATGAGGATGCAACCGCATATGCAATCAACCGTCAAATGGCGATACTTGCGACGATTAG
AAAGCTACAGTTTGAACGAGAAGGCATTTAATGAGTATTATGAAATGGGTGGAATAAGAAATGCAATCGAATTCTGA
AAGATTTATCTATTTATACAAGTAAGGTAGTTTACAATAAAGAGCATGTATATTATTTAAACCAATCAGGACATAAGTTG
TTTGGCGAAGGGAAAGTTGTACATCATGGTAAAGTTACACACGCTCTTTTACGTAATGAAGCTTGGTTAAATTTATATTG
TCCTGATGATTGGCAAGTAGAACTGAAATTAATATATAAAGGATAATAAAAAAGAAAAAATAATTCAGATGTGAAAT
TTCTGTATGAGGACAGAAATCTCATGCTGTAGAAATAGACGTACTCAGAAAAATGATAGTGAACGATGAAAAATTA
AAATATGAGGAGTTAACGCAGATTTATAAACAGAGCATAACGGGAAAGTGCCAGTTATTCAATTTCTTACAATCACAAA
ATATAGAGAAAAGAAATTAGAAGAACTGGCAAAATAATATAATGTGTTGTAAAAGTATATGTAATCGCTACTACTTAAT
GATGAAAAAAGAGCTGATCATTTTGAATGATTAGCTCTTTTTTATGATTGTTATTACGTCGCTATTFTTGTAATTTT
ATTAATTCCTTTTTCTGAGCAATGGCATTTAAAGCATCAATGATAGCTTCAAGCGAATCAAAACGAACAGCATTAGCAT
TACCATTCACATAAATCAATACTGTTGTATCTTACTTGGGATTCTGTAGATAATTTATTTTTAGTGATCCCCAATTCA
TCTAAAGAATTTCCGAGTGTGAATTTCAATTTATTTCTCTCCGACGACTGGTTATCTGTACTCATTTTACAACATCAA
TCGAAATTAGTAAACTTTTTCTGTTCAACTATTGACGTTGAATAATTAGAGAGTTATAATTCAACTTAAATAGTTGAAC
TAATTTAGTTGAACTTAAAAGGAGGAACAATTATGAATCGAGTAAATGATTATTTTGGTTTGAAGTAAATCAGATTGC
ATTTGGTTTATGGTTTCTTCAGTATATCTACGATTTTATTTTTAATCGATATGATTATGCTCTTATATAAGGAGGGGA
GAAAAATGCTTAGCTACGCAAACTATACGCAATATAAAAAATTACAATCATTCCGATCAGTAGAAGAGATGAATGAAGCGA
TTTGTCTTTTTTATACAAACATACACATGAATTAATCCGAATCAGCAATAAAAGTATTGAAATTTCTAGCAAGGCACTCT
TGTAATAATCCAGGTGTCTCTTTCTTGAAGGTAGGACAATTGCGGAGGCATTAAATATAAGTGATCGAATCTGTCGAG
GGTACTAAAAGTATTAGAGGATTTTGAAGTAGTAACATAGACATAAAACAAATTCGAACGGAAGGAAAAATACGTGGAGGGA

FIGURE 2

ACGGACATAACGTCTATGTCCTTCTAAAAAATATAGTGTACACACCGAATGTCTTACCGAAAATGTACAGCGACAAGAT
GAAGAAAACCTTACAGAAATCAAAGGTTTCAGATACAAAAACGGACAAGGAAGCTAAACTTTCTGAATCACACCCTCTAGA
AGAATTGAAAAGCGAATTAAACGTAAAAAGAAACGTACAGCAAGGGAATCTAAAGAAAATCGAATTAGAGGATCTAGATGAAA
CTTTTACACCAGAAAATGTACCAAGCCAATTCAGAGATGTGGTAGCTCCATTCTTCAAATCAGCAGATAAAAATTTATAAA
TTGTATCATCGAGTATTAAATAGCTTATAAACGTTCAAAAAATAGACAAGCCTATTGAACAAGTGATAAATCAAGCCATTCA
AGCATTCAAAGAACTGTCTTCGCAGAAAAAGCAAATAAAATTAGAAGTACTTTTGAAGGTTATTTTTATAGAATTGTGTG
AAAGTAAATTTGTAATGGAGAGAAGGAAAGAATGTCTGAGGATTATTGTTCGATTGGTTAAATGAATAATATAAAAATTGCC
CACAGGGAAAAATATATATATAAATTTAATTATCATATTCTTAGTAAATAAGTGGGTGAAAAATTTTGAAATACGCTGTTF
TGTACGAGTTTCAACGGATAGAGATGAGCAAGTTTCATCTGTGTGAAAATCAGATTGATATTTGTCGATATTGGTTAGAAA
AAAACGGATATGAGTGGGATCCAAATGCAGTATATTTTGACGATGGTATTCTGGTACAGCTTGGTTAGAACGTCATGCG
ATGCAACTAATATTAGAAAAAGCAAGACGAAATGAATTGGATACAGTCGTATTTAAATCTATACACCGTTTAGCAAGGGA
TCTAAGGGATGCCCTTAGAAATTAAGAAAATCTAATAGGTCATGGGATACGCTTGGTTACAATTGAAGAAAATTACGATA
GTTTATATGAAGGTGGCAATGATATTAATTCGAAATGTTTGCCATGTTTGGCTGCACAATTACCTAAAACCTATATCTGTA
TCTGTTTCTGCTGCAATGCAAGCTAAAGCAAGAAGAGCGAGTTTATGGGAAAACCGGGATTAGGATACGATGTAATTGA
CAAGAAACTTGTATCAATGAAAAGGAAGCTGAAATTTGTAAGGGAATTTTGTATTATCTTATAAAGGCTATGGATTTA
AGAAAATAGCGAATATCCTAAACGATAAAGGCACATATACGAAGTTTGGCCAGTTATGGTCGCATACAACGTAGGGGAAG
ATTTTAAAGAACCGAGCGTATAAGGGGAATTTGGTCTTAAATAGTTATAAAACAGTAAAAGTAGATGGAAAGAAGAAAAG
AGTTTACACTCCGAAAGAGAGATTAACAATTATAGAAGACCATTATCCAACAATTGTATCAAAAGAAATTTAGGAATGCGG
TAAATAGCGATAGGGCAAGTAAAAAGAAAACAAAACAAGATACAAGAAATGAATTTAGAGGAATGATGTTTTGTAAACAT
TGTGGTGAGCCAATTACAGCTAAGTATTCAAGTAGATACGCAAAAGGAAGTAAAAAGAGTGGGTATATAGAAATGCAG
TAATTATATTAGATTCAATCGCTGCGTTAACTTTGACCGGCTCATTATGATGATATAAGAGAGGCGATTATCTATGGAT
TGAAGCAGCAAGAAAAAGAACTAGAGATACATTTCAATCCAAAAATGCATCAAAAAAGAAATGATAAATCTACAGAAAT
AAGAAGCAAAATTAAGTTGTTAAAAAGTGA AAAAGAGAAAGTTGATTGATTATACGTAGAAGGATTAATCGATAAAGAAAT
GTTTTCGAAGCGGGATCTTAATTTGAGAAATGAATTAAGAGCAAGAGTTGGCATTACTTAAATTAACAGATCAGATA
AGAGAAATAAAGAAAGAGAAAAAAATTAAGAACTTTTCAATGCTCGATGAAGAAAAAGATATGCATGAGGTTTTTAAA
ACTTTAATAAAGAAAATCACACTTAGTAAGGATAAGTATATCGACATCGAATATACATTTTCTTTATAGTTTTAAAGTTG
GTATTAGTTACTGTGATATTATCACGGTACCCAATAACCAATGAATATTGATAAATTGACATTTTATAGTAAACAT
ATTTTCTCAATATGAGAATTGCGCTTTACAGAACACATGCTCTCATTAATGTGATAAAATATTCTGTAAATATAATGGAA
AAAGTGTGCTTATTGAAATGAAGGGGTAACTTACTGAAATTTATGAAATTTATGAGGATGATTGAGGATAGGGA
TGACTTAACAGCTACTAGTGTAGCGTGTAAATTTGGCGTTTCAAAACAATACATGTCAAAATTCAAAAGACAAGGAATA
TTGGATTCTCTCAATTATTGAAGCTAGCACCTATTTTGAGCGTTGAAGGAAAAAGCAAAGCAAACCTATGTCGGATTGG
TGTTTAGAATTAGATACCACAGAGTCTATAAAACAAAGTTTTGAATATGCGTGTCTAACTCGTAATACAATTTTATTGAA
ACAATTAATACAAAAGCATAGCAAGAACTGGAACAATCCGAGAAATATGTTGAAGTGTATACAATCTGTGTTAAATATA
TTAAGAAATATAAATAAGGCTCGAAAATAACAAAGGAATTAAGAAAGATTGGTGCTATTAAAGATAAGGTTTTAGAGATA
TTAACAAGATTATGGAATGCTATGAATATTATCATCTAAAAAATTCATTTAATGTTGGAACATGCAGAAACGATTGA
TTCCTGTTAGAGAAATTAAGGAGAACGAAAATCCTTCATTAAAGGAATGTTACAATATCGTATTGCTGAATTGTTTG
CGCCGATTTTCTTACAAAAGAAATATGTAGATTTGGCTAGGAAGTATGCCCACTTCTTAATTCATGCTAATGTTGTACA
AAAAAGTCTCTGACGCATATTACATATTAGGTATGTCAAATGTATTAGAAAGTAAAGAACAAATGTTTGTCAATTTAAA
AAAGAGTTACTTGTAAAGTAAGGAAATTAGGGATGCTGATATTGAACAAGAGGCGAGATACAATCTAGATGTTGCTAAAA
TCTATTTTGGGGTAAAACTAGACGAAGACGCTGACAGTAGGTTATTACTGTACCAAAAAAACCAACATGTGAATTGTCA
ATTATAGCTCTCCAAGATATAATAAGAGACAGAGGAGACAAGGACTTTTAAATTTATTTATAGCATGTTCTTCCGATGA
AATCGAATGTTTATACGATTGTTTATCAATACITCTACCAAGCTAACTATCTATTTTCAGCGATAGTAGCAAAAGAAAT
TGTGTAATAGAGGGGATAAATCTTTGTTGACTCAATCGATGGTTAAATTTAGGGAATGAAAAACAAAAGGGGTGTTGAT
ATTGAAGAAATTAGTATTAGCAGTTGTACATTTTAAACGTTTAAACAGTGGGATTGTCGATAAATGAAAATGTCAGATA
TAGATAAAAAAATGCAATGTTGAAATTAACCTGGTGGGTAAGGATATTTTAAAGAGCGGATTAAAGACCGCTCTTTT
TTTGTGGTAACTAAAAATGAAAAAATAAAGTAATTTACTTTCTGAATTTTCCCTAGAGGAAAGGTTATAATTTGGATT
ATAGCAGTTGAGGGGAATAGAAATGAAAAAGAAAGTATTTTAAAGGTCATTTTAAATGTGTAATTTCAATGTTCAAT
AGTGAATTTGAGTTCAATCAACTATTGAAGTAGCGTTTAAATGTTGAACAAAAAATAAAAAATAGCGATGAAGTAACAC
TACATCACTATTTTGAAGTACTTTTAAATTTTCTAGACTTTCCATCATTGTTAGCATGTTTGTGAAGACAATTTCTTGA
TGTTCTCAGGTAGTTGTTCTAAACGGTTTTTTATGTGCAAGTACTTTTGATTATATCCGATCTAATTCACGAGAGTC
AGATCGTCTTAAGAGATAATCAACAGGTACACCAAGAAAATCAGCTGCAGGTTCAACGGTTCTCTAGATGCAGGTTTAA
ATCCAGTTTCAAACTTAGAAAACGCTACCTGCAGTAACACCGATAGCTTGTCGAAGATCATGTTGTGTTAAATTCGGTCT
CTTCGTAATTGACGTAACCGATCTTTAAATTCACAATAATCACTCATAAAGTGGTTTGTAGGATTATATAATTTCT
CTAAGGGAAAAATCAATCCGAGTTATTTCTAAGAAATGATAAAAATATGTTGTA AAAATATACTTTGAATTTTCCCTAAGG
GAATGTTAAGGTGATTTACAAAGATATAGAAAGGAGTTACCACATGAAAGTAATTAAGACGAGACAAAATTTAAAGCTG
CATTCAAAAATCTGGGTATAAGTATCAAGAGTTAGCTGACGAATTAGAAATATCCTGCAGCTACTGTTACAAGCTAATT
ACAATCATAATTACAAAAGAAAATATCGTATAACTTAGCATCCGAATGGCGCATGTATTAAATGCAAGTGTAGTTGA

FIGURE 2

TTTGTGTTGAAGAGCAAGTCGATTTTTTTTTaATACCAATATTCCCTGAGGGAACATAGGGGTGAGAGGGCCATGTCAGAAA
TTTATTACAAAGGGTTTATCATCAAGGAACTTATGGCGAAAGAAATATCGAAGAAGTGTTTAAAGAAGCATATGAGTCA
TTTTATGGGGTTGAAGTTAAGGTGTTTAAAAAGGAATTAGGGACTAAACGCAATAGTGCAGCCAGCTAATCTTTAACTT
CAGTGAGAACATTCAATGAAGTCGATTATAAAATGGACAAGCCTGAAAGGAGAGAAATGAATGAAAACGGGAAAAGGTT
GACTAAACGTGAAAAATGCATCTTAAATCATATAGCTTAAATCTGATAATTTGGTTGGTTTTCAGAAAGCGGATGGAG
AAATGCATTTAGTACACCGTTATACTAGCACAACTCGTGTAATTTCCAAGTTTATAAGTTTAGGAGGGAATAAGATGGATC
AGTTAACAGTAGCAAGTGAATTACGTCTTTTAGGGAGAAGAAAAGTAGCTGGATATGAATTTACTGGAATCGAGGGAGGA
TTTGGTGAAGGTAAAAAAGCAATGTTGGTTTGGATATAGCTACAATTCATAACCAACCATTAAAGAAATCAATCGTCG
CATTAAATGATAATCGCATTCGATTAAAGA TGGTGTGGATATTGTTGATTGAAAAAGTGGTGGCTTTAACCACCACAAT
TATTAACCTTGGTTTTCTCAAATATGCAGATAGCGAAATCAAaTAAATCTACCTTCTATCAGAACGAGGTTACGCAAAA
CTATTAAAAATTTCTCGAAGATGATAAAGCTTGGGAATTATACGACATATTAGTTGATGAGTACTTCAACATGAGAGAAAA
GAATCAAGTGGCTACAGATCCAATGAGTATTTTAAAACTTACATTGCAAGCATTAGAAGGCCAGCAGCAAGCAATCGAAG
AGATAAAGTCGGATGTACAGACTTGAGAGAAAAATACACCATTTATTGCAATTGAATGTGATGAAATCTCTACAGCTGTA
AAACGTCAAGGAGTCATATTGTTAGGTGGAAAAAGTCTAATGCCTATCGAAATCGTGGATTAAAGGGGAAAGTTTATCG
TGATATCTACAAACCACTATACCGTGAATTCGGAGTGAAAAGTCAAAAGCAATTAAACGTTGTCATTAAATGTAGCAG
TAAAAATAGTTGAAGAATATACACTTCCAATTGTATTGAGCGAAGAGATTTCTTTTGTAAATGCACAAATGGATTTTACA
GAAATGTAGTTAGTTAAACATTTCTCAACCGGTTTTTTTTCTAAGTTAAAAATTTAAAGAAAAGGTGGAAAAGACAATGGa
CCAGTTACGTGTTATTGAGGGAGAAAAAGTGATAAGCCAGATTATGTTGAGATaTACCTTGGAGCATTATGTAATGCAG
TTAATGAGTTAAAGAAACAGGATGAGGAAACGAGATCATTAAAGCAAGGATACGTATAAAAAAGCAATTTTTTATGGAGTT
AGATACTTTCAATATCAAAAAATGACAGTTTGAATTATGACTACCTAATGAATGATTCTTTTAAATAGCTATTGGAG
AAATTTGATGAAGGTGTTGACGCTTAGGGATTTTATGACCATATTCCCAATCGATAAAAAATTTATGATGGCGCTCGTTATG
AAATGAAAGATTACTTTTTTACCATGAATGAAATTAAAAAAATCGGAATGGATACACCTATTGGAGAGAAAATCATGGAG
TTTTTATGGGATTACCAAACTTTAAAGATATAACACTATTTAACTTAGCCTCTGTAAGCATTTTAAATAAATTCAGAA
AATGCAAGGTAAAAAACGTTAACTGAAGAGTTTGCCGAGCGATTAGGTATCGATACTTACCGAAGCATAAAGAAAGG
GTGGAAGAAATATATTACAAATGACCGTACTGCTGAGATCGGAAGAGTAAAAAATCTAGACCAAGATATTTAAACCA
GTTCAATGATTGATGTTATTAAAGGCTTATAACAAAGAAAGTAACTTGCGCCAACAAGTTACTAAATAAAAAATCTTATA
AAAATATACTTATTAGAAATATAACATACACACTCGATGTATGGAAGGGTGTATTATGGCTCTTTTATGAAAAGTGCA
TACAGAATTTGGACAGACGTAAAAAGTATCAGAAGATATGACGCCAGAAGACAAATTTGTTTATGGTGTACCTTTTAACTA
ATCCCCATCAACTCAATTGGGAGTATATGAAATCACACCTAAGCTGATAGCTTTTGAAATCGGACTATCAATAGAGTCG
GCTAGAGCACTATTGGAACGTTTTGAAAACCATCATAAATTAATTAATATAACAACTGACAAAGAGAAATGCTATAAAA
AAATTTGGGGCAATACAACTGAATAGAGGCGGGAACCAATTGAAGATTGTCTTAAAGAGAAATTGATAAAGTGAAG
ATTTATCTCTAATAAAATTCATTTTAGAACATACAGATCATGCGCTTTAAAGAGAAAAATCAATCTTTATGCGGGTTTT
GACGATACGTCCCACGATACGTTAGCGATACGTGACCAAGAAGAAAGAAAGAAACAAAAAAGAAACAAAAAGAAACA
AGAAGAAAAAGAAAAAGAAAAAGAAAAACAAAAAGAAAGAAAGAAAGAAAGAAAGAAAGAAAGAAAGAAAGAAAGAA
AAGCGTCTTTAAATCAGACGCAAAAGTCCAATCCAATACCGTATAAAGATATATTGGATTACTTGAATGAAAAAGCAAT
AAAAATTTCAATCCTAAAGCAGAAGGACATAGAAAGTTAATTCGCGCTAGATGGAATGAGGGGTATAAACTAGAGGACTT
TAAAAAAGTTATCGATAACAACTACGCAATGGTTTGGTAAAGAAAGTTTGGATGGAAGAACCACTAGATCAATTTTAA
GACCGAGCACGTTATTGACAAAAACATTTTGACAACCTACTTAAATGAAACGGTCAACATATCCAATCAACAACATGGA
GATCAGATTGTTATACCTGGATTTAGGGGGGAAATGCCGTTTTTGAAGAGGAGTACTAAATGTGAAAAAGATACAAGATTCT
TTTTGAAAAACTTACTAAGTTAAAAATTTGCAGATGAACAATGTGATAAGCACACCTTTAATAAACATGGGAAAGAGTTA
TTAAATTAGTTAGGAAAATGATTGATGATGCAGGAACGGTATATTGTCCCCGCTGCATGGTTGAAGAGCAAAATTCAGTT
TTATTTCAACAGCAAAATTAATCATTATAAAAAAGATTAATAGAGAACGGAAGAAAAATGTACTCTTTCAACACAGCATCAT
AGAAAAATCAATCCATTACAGAAATCAAGATTGTCTACATACAAGACGGATTGTCAAGAAACGAAAGAAAAACAAAGAAAAAG
CTATAAAATTTCTTGAACGCATAAAAACCGTGAGTTTTTAAATGTATACATTGCAGGGATTCAAGGAGTAGGAAAAAGC
CATTTAGCGTATGCGATGCTGTATGAATTAGTTAAACACTATTGGGTAATATCAGACGGTGAGAAATTAATGACGAACA
TGCTTTTAAAAATATGAAAAGCTGCTTATTTGTAGAGATTGAAAAGCTAATTCGATTAAATACAGCACTCTTTTAGAAATA
TAGAGTCAAAAATATACAAATGGATTATTGTATCAGTTAATGGTATGATGGAATTTCCCTGTAATCGATGATTTAGGAGCT
GAAAGTGGTTTCGATGAATCGAAACGGAGAAGCAAGCGATTTTGTTTCATAAAATACTTTATGGTGTACAAATGGACGGCA
AGGAGCAAAATAAAACAAATTAACAATCTCAAACTCTGCAAGCGCTCAATTATTTCAAAAATACGATCCGAAACTAGCAA
GTAGATTGTTAAACGGTGTATCGAAAGTGAACAATTTGTTTTTAAaCAACCACTGACAAACGAATTGTAAATTTAGAC
ATTGGATTCTAATAAAAGGGGTGCGGAGAAATGAAAGAGGTAAAGGGGAAAAACCAAAATTAATGGAAGAAATTTGACGT
GTTATTAAGACAACCTGCTGATTAAATCTAAAACAGATGAAAGGGTAAAAAATTTTTGGATGATCTGTTTGAATGCTAA
GTGATAATAAGCTGCAGTCTGATATTGATTTCAAAACAGCATTAAATAAAGTTAAGAGAAAAGCACTTTCTAAGTTTGAT
AAAGGAGAGAGCAAAATGACTAAAGAAAAGGACAGCTAAGGAAGTAGTTAATGTTCTGTTGAAATGTCAGATGAGT
TTATAGAGAAATACGGAAGGCTTGTACATCATTCGCTATGGAAGAGATATGCGAAAAAAGGCGAGTATAGAGCGGTGAT
ACCGGTTTAGATATTGAGGATTTAACA CAATTCGGAATGATCGGTTTGATAAAGGCGCGAGATAATTTTGACCTTGAATT
TGGATGTGCGTTTTCAACGTATGCTGTTCCGAAAATATTGAGGGAATAGGAAGGGCAATTCGGGATAACCAAAAAATAA

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FIGURE 2

AAGTTCAAAGAACCCTATATGGCGTAAAGGAAAGATTTTAAATCAACAGTTAGCAGATAAAGAACCAGAAGAAATAGCA
GACATTTTGGATGAGTCAGTATCTTTAGTAAAGACGGCTTTAGAGTATCAACCAAGCACAGATTCACCTCAATAAGGTTGT
ATATGCATCTGGAGCTAATGAAGAACTGACATTAGAAAGAATGATAGAGGATACAAAAACGGAAGACATTGAAGAAACAA
CCATTAATCGAGCTGTGATAAGAGAATTTAAAGCTGCATTGCTCTCTAAAGAATATATCGTTTTAGATATGCGTTTACAA
AATATGACGCAACAAACATTGCAATCAAAATGGGATACAGTCAGGTACAAATTAGCCGTATATTAGCAAAGATTAATCA
AAGAGCTGCTCAATTTGGTAAAGAAGGAGGGCTTCAAGATTGAGTGTACAAAAGGTGTTGTATCGATGTAGATCACTC
AGATTTGCTACATGAGAAAGTAGAGTACTTTTTATTCCCTGCTAAACCAAGTCATTACTATGTAAGCAGATTTAATCGTA
AAGGAGCGCATTTTGGTTGTTATCAAGCTGAAAGGTTTCAAAATCACGGGAAAAGGAAGTATGGACACCAGAACCTCAACCG
AATCTGCCTGAGTTGAATACAAGCTTATTCTATAGAGTCAGTTGATTGGCGAAAAAAGGGGTATAAAGATAAACCACT
TAAAGACTACATCGTACAGCCGAGAGGGAACATTGCTACTTTTGGCATGATCGGGAGCGAAAGAAATTTGTGGCTGTT
TTCCGCTACATTTGGTTTACCGATTTTGTACCAGTTCAAAGTCATCATATAGAAGAAAACTAGAGAAGAGGTTAAGTTA
TTACAACGGCCAGATGGACAACCTTGCTATTTTTTAAACGAAAGAAAGTGAATGGGCGTTTTACCCAGTCATCGATTTAAAA
AAAGGAGTGTTCGTAATGGATATTAATAAGTTATTTGCAATGCAGAACATTTTGGATAAAAGAGTTTGTAGACTCAAAAA
TCCTTTCTAGAGGAGAAGTATTGCAATTTAGAATACTAGCGTTTTTAGATGAATTAGGCGAATGCATGAAGGAATGGCGAG
TATTTAAGTTTGGAGCGACGATCGTAAACCGAGAAGTACGTTTTTGGCATGATCGGGAGCGAAAGAAATTTGTGGCTGTT
GAAGTAGAAGTTTATAAAAAACCTTTACTTGAGGAATATGTGGACGGACTACATTTTGCATTTGGACTTTGCTATAGATTT
GAAAACAGAAATTAACCTTCTGCTTCTATGCGTTGCGAGACAGTTACAGAGCAATTTTTCGAATTTGTATCATCTAGCAA
TACGATTTAAAGAAGAACCGACAGCATTTAGGGCAGATGTTCTTTTATCCCATTTATCTTGGTTTAGGGGAATTTGTGTGC
TTTTCGTTAGAAGAAATTTGACATGAGTACATTGAGAAAAACAAATCAATCATGAACGTCAAAGTAATGGTACTAATA
CAATTTGAATTTTGTAAAGAAAAAGTGAAGTGAAGATGGAAGTATTATGAAGTATAGAATTTCAATATTTGGGAATCTATA
TTAATTTATATAATTTAAAAATGTGGTAAATGGTTAAGATTTTAAATATAGGGAATTTATGAAGTGTAGTATGATTGTGATT
GCTGCTTTAACTTTTTATAGTAATTTTATATATTGTAGGGTGCAATTTGAAGAAGTATGGGGGGGAGAAAAATGGATT
GTTTTAAAAAAGGTAAATTTATACCATTTCCATGTGCTTTACCAATTTCTGAAGCTGGCTCTACTGGCCCACTGGTCCA
CCTGGATCAGCTGGAGGCTCGACCGGTCCAACCTGGTCCAACCGGCCCGCAGGTTTACAAGGGATTCAAGGGGTTCAAGG
GAATCCAGGAACCTACGGACCTCAAGGAATTTCAAGGAATTTCAAGGAATTTCCAGGGGTTTCAAGGTCTATTGGTCTTATTG
GTCCTACTGGAATCCAAGGAGTTCAAGGCATTCAAGGATTTCTTGGCATTCCAGGTCTTATGGGCCCCGATAGGACTAACC
GGTCCGACTGGTATCCAAGGTATTCAAGGGATTCAAGGGAGTTCAAGGTATCCAAGGTATTCAAGGGGATGTAGGCCCAAC
TGGCCCTCAGGGAATTTCCGGGTATTCCAGGATTAACCTGGCCCACTGGCTCTCAAGGTGTTACTGGAGTTACTGGCCCAT
CCGGAGGCCACCAGGTCCAACCTGGTGCACAGGTCCAACCGGTCCAAGCTGGAGGCCACCAGGTCCAACAGGTCCGAAC
GGTCCAGCTGGAGGTCCAACAGGATTAACCTGGCCGACTGGCCGACTGGTCCAACAGGAATTTCAAGGTATTCAAGGGG
ACAGGGTACTCAAGGTATTCCGGGTCCAACCTGGTCCAACAGGAATTTCAAGGAGTTCAAGGACTTTCAAGGAATACCAGGCA
TTCCAGGTTCTATGGGCCCAACAGGACTAATCTGGTCCGACTGGGCTTCAAGGTATTCAAGGGATTCAAGGGGAATCCAGGT
CCGACTGGTCCCTTTGGCCCGACTGGCCCGACCGGGCTTCAAGGTATTCAAGGCTTACAGGGTATTCAAGGTATTCCAGG
t t c c a a c a g g a c t c a a g g a a t c c a a g g t c c a a c a g g a c t t g t a g c a c a t t t c c a c a a a a g c t a t t c t t t t t t g g g g g
TACTAATTCAGGGTTTCAACGTATAGCTGGATCACCGGTGCAGATTACAAGACATTCCTTATGTACTTGGCGGAGCTG
GTAGTGTGTAGGTCTTTCTGCTTCTATAAGTATTAATAATTTACCAATAGGAGTATATACAATACAGGTATGTAAAAAT
GTTCCTATTAACTTTGCTGCTCCGGGGCTTGGCCAAGTAATATCTACAATTTATCTTACAACCTACAGCAGTATGATTAGT
CACTATTATATTGACTATTAATCTCTGATATTGGTGCACAACTGTGATAGTTGCAAGAGGTGATGCAATGTCACTTTTATAACTCCA
CTGCTACAGTTGCTTGGAGCAGTACAATACCTGGTGACATAGTTGCAAGAGGTGATGCAATGTCACTTTTATAACTCCA
GGTATTACGCAAAATGCTGTGTATACAGTATTTCTGCATACAGGAATTAAGTTTATTTTATGTGAATTTAAGTCCTGT
AAATTTGAATGAAAAATTAAGATATGTATCGGAGTCTTTTATGTACAAAAGAATAAGAGATTTCTTCTGAACATCTAAA
AGGAATCTCTTATTCTTAATCGATAAATTAGGTTTTAGAAAAATGAAAAGATTTTGTATGAAAAATAAATAAAGAATCCA
TTCTGTACAAACGGATTCTTCCACAAGGTGTGTAAAGAAATTTCAAGATAACTCGACCAGAGCATCATGTAGAAATTTCTTG
TGATATTAAATGATTTCAAAGACATCCAAAAGATGAATGGCAATTAATAAATCTTTATTTGAAAAATTAAGATTGCTTT
TGTTAGGGTCTCTATGACTAAGAGTTATCTTAATTTTATAGGTTTATGAAGTATTTGAGTAATAATTTAGTTTCAGACAA
AGGTGATGTTTAGTAGTAATACCGGTTTGTCTTCAAGTAGACATTGCAATTTGCTTTTGTTCATGAACCTGACCATATGGAT
GTTCTGGAGGTGCATATATAGCGTAAATTTAAGTGTGTATTTCTGTATTGATTACATTATGCCATTTTCCAGCAGGT
ATCATAATTGCATAGTCATCATAGACATTTCTTGAAAAATCTAATTTATCTTTGTTATCACCCATTTGAACGAGTCCCTG
GCCCTCTTCAATACGTATGAATTTGATCAGTTGTAGGGTGACTTCTTAAACCTATGTCATCTCCAACATTAATACTCATTA
AAGTTACTTTGTAAGTTTCTCTGTCCAGATAGCGGTGCGGTAAGTATGTTTGTGTTAGTGGCTTGGTTAATATTCAAT
ACAAATGGTCTAGCTCCATAATCTGTTAATCTAACATTTTCACAATAAGGATTCGGTTGCGGGTTCCAAGCATTATTGTT
GTAATTTGTAATAATAAGGATTCCAAGCGTAAATCCAATTTATTGTTATTTCCAGATGCTATCCATTGGGCTTTGAGATTGAT
AATAATAACGTGGAATATGTTGCATATCCAAGCTCTCTCATAATTTGATCATTTTATCTTTATCTTATGCTGTGTGCTA
TTTATAGGAATGCAGAATAAGGGGAATGGGCGAGTAATAAAAAATATAAAAAAACGTTTTTATTTTTTTCAGGAAAAATAA
AAGTAACAAGTTAATAAGGGATGTACTACTGGTATAAAAACTTAATAAAATAGTTATTTGAATTAATAAGAGCGCCGTT
GGAGAGTGGGCTGCTCTTAGACCAAGAACTATAACAGGGATTAAGGAAAGAAATTTGTATACCAAAATTGATAGTAATGCA
AGCCATCCAATTTGTCAGCGCTATGTATTTAAAAATTTTCATGATTACTCTTTTAGGTATAGAGTGCACCAAGCAAGAGG

FIGURE 2

ATGTTATTAATTTTTTAAACAAAATGCTTATTTAAAACTAAAGAGGGCTTTTTAAAGCGCTCCTTAAGAAAAATAAAAA
GAATACCTCATGATACTGTATGTATGTTTTTTTAGGAATGTGAGGATTTAAAAACAAAATCGTTATTTTATAGATCGGAGT
GAAATTCAAATGATTGTTAAAGCGACAAATAAACTTGAATTAGATGATTTCGAGAAAAATTTGGGTTTCTTATGTTAGAGA
ACAAGGTGGAGAAGAAGCGGTATTTTCATTATCTGGAAGAAGAAGTGCAGAAAGAAAATTTGAATTAGCTGATTTTGTGGAGA
TGAATACAAAAATAAGTAAATTTAAACAAAAACGCTATTTTATAAAATAAACAGCTAGCGTGATTAGCTGCTGCTCTG
TTAAGAAAAGAAAACGGTGTTTTAGCAAAATGTGCTGTTGTAATTGCGAATTACAACCATAGTATGAGCAGAAGTAAAAAT
GTTATGCAAGAAAGTTAAATAAAAACTGCATTTTATTGAAAAGGGGGAATGGATATGTCTCTAGTAGGGAATTTAAAGGA
ACTCCAAGAAAAAGCCATCGATGAAAAGGTATTGGAATTTGCGGAAGAAAATGGAAATCGTAATAACTAAAAGTGCCGCAA
GCGGATATTCAGGTTCATAGATATAAGATTCAATAAGAAAATCCAAATCGGCATATGATGTGTTCAAAAAATTTTATAGAA
AAGTTACAAGAATTACTGGACGGTGTGAAGGTTGAATTTAAGGAAGAAGAAAAGAAAATATTTTAGCGGATCTTACTA
CGAACATTACATCCGTTTTTAAGTGAATGACTAATTTCTTATTAATAATTTTATTTTGGAGAAAGGGAGTAGAAGAATG
AAAACTTTTAATGTGACTTTTACAGAGTTGAAAATATATGAAGCAGTCATTGAAGCGGAGTCAGCGAAAAGATTATGGA
TGTGATTAAACACTTAAAGAACTGAAGATGATTTAGTAGACAAAGGAGTCATCATAAACGGAAGTTAGTGAGATAAATG
TTAGTAAAGAACAAAAGTTTGAATAAATCAACTTCTCAGATTGTTTATTTTGGAGACGGAACAACTTTCTGAATATCATA
AGACCTTATTAGCGAAAAAaCTCTTATTTCGAGCGTACAAGCCGTGTATACACGTTGACCGGAAATTAGAATGAATTTGTT
AAGGAAGGAAGTATAAAAAATGAGGGCTTGGGAAGAAAAACATGTTAAAAGAGCATTTTTGAATCGTCAAAAGGAAATGGA
TAAAGAACGGACTGCTGCAGCTTGGAGAAAATTTTTTGTGAATCAGGAATCATAAAATAAAAAAGGAAAAGCAACTCGT
TGGGGACAGTCACTTTTCCAGATGGCAATGTAAATCCATTATAGCAAAACaTATGTACaAGCTGTAGCAATAAACCAACG
AGATATTTTGACACCTATCGACAATTAGAAAATGTGGTTGTTGATCTAGAAAATAGAAAGTAGGTGAATCATCATTGTTT
AATGGCTGAGAGATTACCAAAAGTTAGAAGAAGACATAGCCCTATCTGGAATACAACCTAGATTAAGACAAAAGCTGAATT
AAGACGCTGGGTGAGTGGTGATTGAGAGAAGTACGTTTAAACGGCAGAACTGTAAGGTGCAAAAGTTGAAAACCGCATG
AAGCGATTGAATACGAATTAGCACATAAGATGAACGATATGTATAAATTAAAAAGTTAATTAGTAAGTTTAGAGGTTTA
GAAAATCAGATACTCAAAATTAATAATATGTGGATGGTATGACGTTAGAAGAAAATAGCAGAGGCAGTAAATTATAGTTCTAG
TCATATCAAAAAGAAACATGCTGAACCTCGTTAGATTAAATTAAGTTCGTGGAGCGAGAAGGTGTCATTAGGTTCACTCTT
AAAATGAATCGAAACGGTTGAAAAAATGATTTATATTATAGGCATACAATTTTAGCAGAAGGGCACTGGTGACCGGTTG
CTCTTTTGTATTTGGAGGTTATTAGACGATGGATGTACAAGAGTTGTCGAGACGATTAGAAAATCTAGAACATAAAGTG
CTTCAGGTAGAAACGAAGGCAGATGTGCTAAACCGAACAGCTATACAAAAGGCGATAAAAATAAAAGTGGTGTATCCGCA
TTTAGGGATACAAGGCGAGTATTTAGTGGAGAAAATGTATAATGGTGTGTTGGAAATGGTAGCAGAAGAAACAATGAAAA
AAATACAGGAGTGATTAGGATTGAAGAAGTTATCTAAACAAGAGCTAGCAGCTGTAATGACACATTGTATTTCAACGCTT
GGTGAGCAGATTGTTAATGAGCATATTAAATCCCAAGTTGGCGCAAGCAAGTGCACTCCATAACGATCTCTTTGATAA
TACCCTCTTAAAGAACGTAGGGAAGCGACGATCAGTTTACTAGGGAAGCGATTGATGAGTTTTTAGAGAGTAAGGAGT
GAGGATATGGGAAAGGGATATTTAATAAGGCTGTATGTTTAGTGTGTTGTCATCAAGATAGAGTGAATCATCCATCTAA
AAAAGAGTATCAAGAAGTAACGGTTTGTCCGGAATGCAACGGTGCTTTTGTAGATGTGTGGAAGCTAGGAAAGTACAAAC
GTAATACACAGTCTAATGAAGAACCCTTTATTAACATTTACATTAAACAGATATAGATGCTAAACCGGATAGTTCAATCAAA
GGTGAAACAGATAGATAAGAAAGTTACGTGTTACGTTTGATTGGGAATCTCAATCGATTGATAAAATTAATCGGACATACAT
TCATATTGAACATGTACCAGCCGATAACAAACGTTTAAATACCGAGACCATTACAGCATAATCATCCTATTGCAAAATAAGG
AACAAGTTTAGATGTTGTCCATATTTGTTAATAGGTAAAAGATAAGTGTTTTATCTGGAAGTTCAACCGTGAAATTAAGA
AATTAATAAAGGAATATGAAAAGGAGAGTCACTGAATGAACGGGTTTAAATAAAATTTGTAACGATATGCAAAATGAACAA
GTAGGAAATGCTATGCTAGATTTTGCTTTGGCCGCTAAATGATGTTTCGCTGCCTTTACACAGTTTAAAGAAGCTGGATT
TAACGAAGAGCAGTCATTCCGAATTAACACGTGAGATTAATTTGATTCAATTAAGTAAGAATCAATAGATCAATGAGGTGA
AAGGGAATGCAAGTATATTGCTCTGAGTGTGATAAAAGTTATGACATGCAGCCGCAAGTAACACAACCTCCCTAATCGTAT
TGAGAAGTGTTTCTTTATTTGCTCATTGTAAATCATGAACATATAGCTGCGTACGTAATGATAAGATTGCGTAAGTATC
AAGCAGATATAGCAAGTGTCTAGAGCGGATTAATAAAAAGAATCTTGCTATCGAAGATGAAATGAAACGATTAAAGGAAG
AGGTTTGACAGGAGAAAGTGAGAGGTGAAGCGAGTTTGAAAATGCTATTAACAAAGCATTGGTGTTTAGATAGAACTGCG
GGATTGAAAGAGACTTCTCATAAGGTACGTGATGGTTGGAAATGTCCTGATTGTAATGACCAATGGCGTTTCAACAGGT
GAATAAGAAAAAAGaAAGCGCCAAGTGATGGTGCTTTTTATTTTGGAGGAGGATGAAGGATGGAAGGACAGGAGTTAACA
TTGGAAAAGAAAGACAGTATTTATCTTAGACCAAGATACCCTCATAAGATTGACGCAAGTAAATCAATCCCTTAAAGA
TGTAATTAAGATTTTAGGATTGATGGATATTCGTTTGGACGACAAGGCGGTCAATTTGGTCTAGAACACTTGATTGAAAAGG
AGGAAGAATAAAATGGCCAATAACAAATTAATTATTGAAGTAACCTGCGGATACAACCTGAGGCAATTAGAAGGAATTAAGA
AGTAACCTGAAGCAGCTAATGAATGTGCAGATGCGCTGAGCAAAATTAAGAAAGATTATGGATAAGTTTACAAATCGAAGTG
ATACAGTGGAACCTCTATTGTGAAGGTAAATTTGTTATCGAAGTCTACAGTTAATCATAACAGCTGATTCAATTCAATGTCCG
ATAATCAAGGGAGAAGAGCTTGGAGGAAGTGAACGCTGATGAAGAAACCGCTTAGACCATGCTGCGAATTTTATTGTTAT
AATCTCACACGTGAAAGATATTGTGAGGAACATAGATACAAAGAGAAGGAAACGCAGCAGGATAAGAATAGATACTACGA
CCGATTCAACCGGACAAAGAGAGTACGGCTTTCTATAGTCAAGGCAATGGAAGGTTAAGAGAGCAGGCACTAATGA
GAGACAAAGGGTTGTGCTACATTGTGAAGCAATAGAAAGATTAAAGTTGCAGATATGGTTGACCATATCATTCCAATC
AAAGTTGATCCAAGTTTAAACTCAAATTAGAAAAATTTACAATCACTTTGTAAATCCATGTCAACAGAAAAACAGCAGA
AGACAAAAGAAATACGGGTAGGGGCGGTCGAAAAACATTAGGGCGGTCTGTCCGTACcgcgcgcgc

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FIGURE 2

FIGURE 2A: Polypeptide Sequence of Phage W

W phage proteins, beginning with the first ORF

Orf1 (SEQ ID NO:4)

MAGRNRKQPLSVIQGKGRSNHITKSEKNRREKQEEALRGHTDKIEAPSYLTAAQKKEFDTLAAELVRLKIFSL
NLDVDSLARYVDSKDQYIKMVRLLRKTTPSDDFKLYSQMQRSKNLLFNECRSSASDLGLTITSRLKLVPE
VDTSQKQSEAQRFGDRI

Orf2 (SEQ ID NO:6)

MNWIMERVFAYCEDILNGKINSCKKRWAIERFIRDYEECQSEDSPPFYFDGEIAEDFYWFAKEFKHVEGI
LAGESVELTDFQLFLAANIFGFKKKINGARRFRKVFILARKNAKSQFLAIVAAFCTFLGDEKQRAYIAG
WTRDQSSEVYEAVKTGISSESELLEGKWEAYSTIEIFKNGSVVPLSKEARKTGDGKNPSLGI VDEYHAH
ETDEIYDVLSSGMVARKEPLMFIITTAGFDLSRRCYREYEVSDILDPSKNVENDDYFVMICELEKNDI
KDESNWIKANPIVATYEEGLEGIRSDLKVALDRPEKMRFLTKNMNIWVDKKDNGYMDMSKWQKCEVDTF
DFSGATLWIGGDLSTMTDLTSVGWVGMDDEGDFIVGQHSFMPPEARLKEKMAIDKVRDYLWAEQGYLTLP
GEMVDYTTIVESWIENFSKDKIEQEFDYDKWNALHLAQNLENKGFVCVEIPQRIANLSIPTKNFREKVYEK
KVKHNGDPVLFWALNNVVKMDDQENIMISKKISKNRIDPAAAVLNAFSRAMYGASVRFDVSEFANKDFL
GKLWN

Orf3 (SEQ ID NO:8)

VKIVDSVKKFFNFKEKQTSQVIELNKDDEKLEWLGISPSTISVKGKNALKVATVFACIKILSESVSKLPL
KIYQEDYGIQRTKHYLNLLRLRPNPYMSSMNFSGLEAQKNLYGNSYANIEFDRKGVQALWPIDASK
VTVYIDDVGLLSKTKMWYVNTGGQQRVLKPEEILHFKNGITLDGLVGVPMTMEYLKSTLENSASADKF
IN
NFKYQGLQVKGLVQYVVDLNEADKKVFRENFESESSGLQNSHRIALMPVGYQFQPI SLNMSDAQFLENTEL
TIRQIATAFGIKMHQLNDLSKATLNNIEQQQQQFYTDTLQATLTMYEQEMTYKFLDSELDKGFYSKFNV
AILRADIKTRYEAYRTGIQGGFLKPNEARSKEDLPPEAGGDRLLVNGNMLPIDMAGQAYLKGGDTNGEVSK
EGNEGN

Orf4 (SEQ ID NO:10)

MEKSAKKEMKEIRALPMTIEVREVNEDEGKRTISGSIKYNNEAEMRDWWGDTFVEEIAEGAFDESLKVRD
VVGLWSHDTSQVLGNTKSKTLRIENDKKELRFELDIPNTTVGNDAWELIKRGDVGVSFGMKVTKDKWSSE
ERENGKLYKRSILNAELYEISPAFPAFPTNEVSRSDDDFKAGEKRVADFEFRKRKLQIELELI

Orf5 (SEQ ID NO:12)

MSKELRELLAKLEGKKEEVRSLMGEDKVAEAEQMMEEVRSLOKKIDLQRSLEAEATEERNNGREVETRNVD
GEMEYRDVFMKALRNKPLNAEEREFLIEDDLEQRAMSGLTGEDGGLVLPQDIQTQINELARSFDAQEYVTV
EPVTRSGSRVLEKNSDMIPFAEITEMGEIPETDNPKFSNVQYAVKDRAGILPLSRSLQDSQDNILKYVT
KWLGGKSKVTRNVILGVIEKLTQKAIKSLDDIKDVLNVKLDPAISPNAILLTNQDGFNYLDKLDKDGKY
ILQSDPTQKNKKLFPAGTNPVVVSNRFLKSGTTAKKAPLIIGDLKEAIVLFKREDMELASTDVGGKAFTR
NTLDLRAIQRDDVQMWDNAAVYGEIDLSAPVEQPQG

Orf6 (SEQ ID NO:14)

MLVTLEEAKEWIRVDGDDDPITMLIKAAELYIYKATGKTFTQTNEADKLLCLFLVADWYGNRLLVGEKAS
EKIRTIVQSMILQLQYASEPQEERK

Orf7 (SEQ ID NO:16)

MNPAKLDKRLTFQVKDENAKGPDGDPIDGYKDAFTVWGSFVYLKGRKYFEAAAANSEVQGETEIRNRDDVS
ADMKIKYKNVIYDIVSVIPTQDHTLLIMWKRGEENG

Orf8 (SEQ ID NO:18)

MKLTLMINKEKQTFNMEFIPARLIRQAPELAEIPNNPGPEDMDKMVQFVVVKVYDGGFTLDQYWDGVDARK
FLSTSDVINAIINETVEAAGGSTESGEEENPNA

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FIGURE 2

Orf9 (SEQ ID NO:20)

VINLRPDILQALENDQELVSLGKKRIYYRKAKKAEFPRTYFELDNRPDGFADNQEIIESEILFQVDVWA
KSSTTAIHQKVNEIMKRIGFSRYAVADLYEEDTQIFHYAMRFAKGVEL.

Orf10 (SEQ ID NO:22)

MAGEVVRISSTVGVDNLVYAKVLQDDSSAIKYTDVKKMEGAVKVKLTKKVASEVMWSDNRKSEIAESDGET
EVEIEVRGLSLSTKADIEGFPEVKDGVLDKREGEKPYLAIGFRFLKANDKYRYVWLLKGKLSQEEEEAET
KKDKPNFQTTKLKGSFIERDFDRTKFTADEDEPTFTKLVDNWFNKVYEKPVTPPPAGK

Orf11 (SEQ ID NO:24)

MKLTLMINKEKQTFNMPEFIPARLIRQAPELAEIPNNPGPEDMDKMVQFVVVKVYDQGFTLDQYWDGVDARK
FLSTTSVDVINAIINETVEAAGGSTESGEEENPNA

Orf12 (SEQ ID NO:26)

MDELYLSLLRQGYKHHHIDNEMDIWHYLRNLNRKMHENGNGENYEGSNSNEIEVPAENII

Orf13 (SEQ ID NO:28)

MANEINNVLVRLSLDNVNFQGISNSGRAVRTLQNELKSVSTGMGGFANASQQTQAKMNTLSRLIDAQKEK
VKALRQAYDQNKAKLGENDAATQRYASQVNKAVADLNRNFENELKQVNRQAEQKGMKLNNSLKSQAEEFQS
ITTGMGGFSNATEQTRAKVDVLSRMVDKQKEKIRELQQAYNRAKTEEGEASQSAQRYAEQIHRATAELNRF
ETGLQQSNRELEQQGNRLNFGNRMETLGNHLQNAQMIGMVFGMTYAIGRGLKSAITESMNFQQMANV
KAVSGSTGAEMKKLSELAVNMGETTKYSSVQAGQIEELIKAGVSLQDI INGGLAGALNLATAGELELGEA
AEIASTALNAPKADHLSVADAANILSGAANASATDVRELKYGLSASSAVAAGAGMTFKDTATTLAVFAQNG
LKGS DAGTSLKTMMLRNPSTKEAYNKMRDLGLITYNAQAGFDFLVKNGIQPASRVGDI EVALEQYVMKT
EGVTKWNDKCDTTFRELATSSAFLSSKFYDQQGHIQSLENISGTLHESMKDLTDQQRSMALETLFGSDAVR
GATILFKEGAGKGVNEMWDSMSKVTAADVAATKIDTLKGRLLTLD SAFSTMKKTIGDALAPVVSFVAGLQK
LVDGFNSLPGPVQKAIAITGGIVLALTAVATAIGVVLAAFGMIASGIGSLSLALASVGGIAGIAAGAVGFL
GSALAVLTGPIGLVAAALIGTGVVAYKAYQKATEDSIASVDRFATNTEGKVSSSTKKVLGEYFKLSDGIRQ
KLTEIRLNLHEVITEEQSQKLIGQYDKLANTIIEKTNRQOKEIEGLKKFPADSYVLTAEEENKRIEQLNQH
YEQEKLTQEKENKIKEILQTAARENRELTTSERISLQALQDEMDRVAVEHMSKNQMEQKVIENMRVQAS
EISARQAAEVVENS AKARDKVIDAKKTRDEKIAEAIQRORDENKTITADEANAI IAEAKROYDSTVSTARD
KHKEIVSEAKAQAGEHANQVDWETGQVKSQYQAMKDDVIRKMKEMWSDVTNKYEDMKNSASNKVEEIKNTV
SRKPEEQKKAVTDKMSEIKSSIEDKWNTVEKFFSSINLRSIGKSIIEGLGKGIDDASGGLFSKAAEIASDI
KKTISGALEINSPSKVMI PVGSAVPEGVGVGMDKGRFVVDAAKNVVGVKKQMGNMPSVDFDGFQTNQYS
IPQNTFSDFSGYMQPQLSYNNPSMAKTIFFPNRPGGEQELNLTVMNTNVLDGKELANGSYTYTTKLQNRREQ
RRAEF

Orf14 (Tail fiber...this sequence differs from that in γ) (SEQ ID NO:30)

MGKLSFTFNNIRKDYIQMLVGRKRPSWAPVKRRLVRVPHRAGALLNTETEERRIDVPLVIKAKDMADL
QKLKEDLADWLYTEQPAELIFDDELDRTYLSLIDGSVDLDEIVNRGKGVITFVCPMPYKLGKINTHKFTQ
EWSTETTSYFTNKGSVEAPALIENTVKKPSTFLDVWFGEYPHNRDYFRIGYPLTVEETTQQRERVMWDE
MATPIGWTPVTGQFEEMKGTGSFKSRGGHALYCEDYGKETGFGYGAIAKKNIPGGPLQDFEMEAWVTLLKSK
NISEMGRVEVLLLDETSNVISRINMNDLYATAEITRAHMTIGNSGTPNSFRKLVDTS GFYSTTFNQFRGR
LRIARRGKVWSVYVAKFIDGTEKDGASLVERWIDETGNPMTERRKIAQVMIAICKWDNHQPINEMQIDDLK
IKWVNKVP SNAQPYIFDTGDKIVIDTEKSLVTINGEKAINIKEIFSNFPVVIRGENRIDIMPPDVNATIS
YRERYR

Orf15 (SEQ ID NO:32)

MRTPSGILHVVDPKTDQIVAAIQPEDYWDKRWELKNNVDMLDFTAFDGTDHAVTLQQQNLVLKEVRDGR
IVPYVITETEKNSDTRSITTYASGAWIQIAKSGI IKPQRIESKTVNEFMDLALLGMKWKGIT EYAGFHTM

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FIGURE 2

TIDEYIDPLTFLKKIASLFLKLEIRYRVEIKGSRIIGWYVDMIQKRGHDTGKEIELGKDLVGVTRIEHTRNI
CSALVGVFVKGEQDKVITIESINKGLPYIVDADAFQRWNEHGQHKFGFYTPETEELDMTPKRLLTLMIEIELK
KRVNSSISYEVEAQSIGRIFGLEHELINEGDTIKIKDTGFTPELYLEARVIAGDESFTDSTQDKYBFGDYR
EIVNQNEELRKIYNRILSSLGKQEMIDQLDRLVQEANETASNAKKESEAAKTAEKVQENIKNNTVEIIIE
SKNPPTTGLKPFKTLWRDISIGKPGILKIWTGTAWESVVPDVESVKKETLDQVNKDIAATKTELNQKVQEA
QNQATGQFNEVKESLQGVSRITISNVENKQGEIDKKITKFBQDSSSGFKTSIESLTKKDTESINKLNTVESTV
EGTKKTISEVQQTNDLKKKTTEIEEKAGKITEKLTSLETREVNVRNYVINSDFSNVTNSWIGITNATLFK
FVDVNISEASAIKKGLQITSNAKFVYQKLPADVFKKKKGIASCYINVSSFTPGTDYPRLYMRFTYDQNGTE
KQYYAILKQQEVNTNGWIRISIPFDTTGYTGELKEVRVNIATADTTTIDATFTGIMVTFGDLIESWNLAPED
GVTQGVFQSKTTEIEKSVDGVKTTVTNVQNSQAGFEKRMNSVEQTATGLSSTVSNLNNVVSQDGKKLLEAN
TKLEQQATAIGAKVELKQVEDYVAGFKIPELKQTVDKNKQDLDLDELANKLATEQFNQKMTLIDNRFTINEQ
GINAAAKKTEVYTKTQADGQFATDSYVRDMEXRLQLTEKGVSVSVKENDVXAAINMSKENIKLNAARIDL
GKVNXBWIKAGLLSGCQIRTSNTDNYVSLDDQFIRLYERGVARAFLGHYRRSDGAVQPTFIILGSDEKTNAP
EGTLFMSQAGAGWSGAYASIGISNGIVDGAQSVYVWELQRNGLSVLNANDYHVFYAGNGNWYFRGKPG
YQTSLVVEDNSTDSDLRLPNVTIRNSRAAGYTGVIQLKSPVTQNGWGAQGNFMTPSLREYKSNIRDISFS
ALEKIRSLKIRQFNKNAVNELYRMREEKSPNDPPLTTEDIKTYGLIVDECEMFVDESCKGIHLYSYAS
IGIKGLQEV DATVQEQEVEIANLKSQIASQEDRIARLEELLQQLINKKPEQF

Orf16 (SEQ ID NO:34)

MDRIDVLLKAFIAAFGGFCGYFLGGWDATLKLILVTMVIDYLTGMIAAGYNGELKSKVGFKGIAKKVVFLFL
LVGAAAQLDSALGSNSAIREATIFFFMGNELLSLLENAGRMGIPLPQALTNAVEILGGKQKQEEKGDVQ

Orf17 (PlyG lysin) (SEQ ID NO:36)

MEIQKKLVDPSTKYGTCKPYTMKPKYITVHNTYNDAPAENEVSYSNNNEVSFHIIVDDKKAIQGIPLERN
AWACGDGNGSGNRQSSISVEICYSKSGGDRYKAEADNAVVDVVRQLMSMYNIPINVRTHQSWSGKYCPHML
AEGRWGAFIQKVKNGNVATTSPTKQNI IQSGAFSPYETPDVMGALTSCLKMTADFILQSDGLTYFISKPTSD
AQLKAMKEYLDRKGWYEVK

Orf18 (SEQ ID NO:38)

MKMYKKLISICIGSTLLGLTACDSSKQSESSEKTNVKSQPETKKDLTSQDELNKKIKQDAEEVSFVKAN
GDQYEKGKRLKATGTVDLLKSSALPSFVISTNENDGKGMYYTIQIVQSGVQTNENEITLKNGLKISKGSI
VTIYGAYDEKDKTGMPKISATVIEQ

Orf19 (SEQ ID NO:40)

VRLKCKLRVIFAEREIRQKEFSKLIGISQTTMSSSLVNNTTLPFTLTAYKIAKELKLHMEEIWIEEENENV

Orf20 (SEQ ID NO:42)

MRWQYNHLNTPPYLHPSKELCSMYNGSRSAETESILNHMKNHVYDRKEYKGYFSLSQVLEEDLYGEEED
VLNWEILMDCYDVVLTRKGIAFREKEEEEQEA

Orf21 (SEQ ID NO:44)

MTLAGEAII IWTATGLSVVAMKAAEKMGSVPHWLPRVTLYTTLTGSFLYLLRYVLVFL

Orf22 (SEQ ID NO:46)

mwklfipyvirslacMHVFLETGIYTLKRDIRSDFMLELLSVPFAGLIFAIVGERLKGRESDRKKIQVFF
EVSGIAIRREDKLQYPVFLEQKEDDRSTTYIYRLPVGMPSKI IQKVEDVVSGLSKPVRIDYDNYKLNIRV
FHRDIPKKWSWSKGLVAEGSWCVPMQGSLEKLIYHDFDKTPHMTLGLTRMGKTVFLKNVVTSLTLAQPEH
INLYIIDLKGGLEFGPYKNLKVVSIAEKPAEAFMILTILKKMEEKMEYMKCRHYTNVETNIKERYFII
VDEGAELCPDKSMKKEQQRLLGACQQMLSHIARIGGALCFRLIFCTQYPTGDTLPRQVKQNSDAKLGFRLLP
TQTASSVVIDEAGLETIKSIPGRAIFKIDRLTEIQVPYISNEMMWEHLKGYEVEKHEDANAYANQPSNGDT
CDD

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FIGURE 2

Orf23 (SEQ ID NO:48)

mrwrnmrmqthmqinrqmailatirkqlqfatrrrhmsihemggirnanrilkdlsiytskvvyvynkehvyyyl
NQSGHKLFGEGKVVHHGKVTHALLRNEAWLNLYCPDDWQVETEIKY IKDNKKKKIIPDVKFRDEDRILHAV
EIDRTQKMIVNDEKLKKYBELTQIYKQKHNGKVPVIHFFTITKYREKKLEELANKYNVFKVYVIATT

Orf24 (SEQ ID NO:50)

MKFTLGNSLDELGITKNKLSTESQVRYNTISDLVNGNANAVRFDLSLEAIDALNAIAAEKGINKIYKIDDV
IQYIKKS

Orf25 (SEQ ID NO:52)

MAFKASMIASSESKRTALALPFTKSLIVLYLTWDSVDNLFVIPNSSKEFPVNFILFSSAALVILYSFY
NINRN

Orf26 (SEQ ID NO:54)

MLSSANYTQYKKLQSFRSVEEMNEAICSFYKHTHELSESAIKVLKFLARHSCKIPGVSFLKVGTTIAEALN
ISDRTVRRVLKVLDFEVVTRHKTIRTEGKLRGGNGHNVYVLLKKYSVTPNVLPMKMSQRQDEENLTESKVS
DTKTDKEAKLSESHPLEELKSELNVKETSARESKIELEDLDETFTPENVPSPQFRDVVAPFFKSADKIYKL
YHRVLIAYKRSKIDKPIEQVINQAIQAFKETVFAEKANKIRSTFEGYFYRIVESKFMERRKECRGLLFDW
LNE

Orf27 (SEQ ID NO:56)

LKYAVYVRVSTDREQVSSVENQIDICRYWLEKNGYEWDPNAVYFDDGISGTAWLERHAMQLILEKARNE
LDTVVFKSIXRLARDLRDALEIKEILIGHGIRLVTIRENYDSLYEGGNDIKFEMFAMFAAQLPKTISVSVS
AAMQAKARRGEFIGKPGLYDVIDKKLVINEKEABIVREIFDLSYKGYGFKKIANILNDKGTYTKFGQLWS
HTTVGKILKNQTYKGNLVLSYKTVKVDGKKRVYTPKERLTIIEDHYPTIVSKELWNAVNSDRASKKTK
QDTRNEFRGMMFCKHCGEPI TAKYSGRYAKGSKKEWVYMKCSNYIRFNRCVNFDPAHYDDIREAIIYGLKQ
QEKELEIHFNPKMHQKRNDSKSTEIKKQIKLLKVKEKLIDLYVEGLIDKEMFSKRDLFENEIKEQELALL
KLTDQNKRNKEEKIKEAFSMLDEEKDMHEVFKTLIKKITLSKDKYIDIEYTFSL

Orf28 (This sequence and that of 28.1 below replaces 28 in the γ phage) (SEQ ID NO:58)

MRIALYRTHALINVIKYSVNIMEKVLLIEMKGVSYLKPFHEKIMGMIEDRDDLTATSVACKIGVSKQYMSKF
KRQGTIGFSQLKLAPILSVEGKAKQTMDSWCLELDTTESIKQSFEYACLTRNTILLKQLIQKHSKETGT
IREYVEVYTIILFKYIKNIIGSEITKELKKIGAIKDKVLEILTKIMECYEYHLKKFNLMLTAEITIDSLV
REIEGERKSFIEKCYNYRIAELEFAPIFLQKNNVDLARKYAHFLIHANVCTKTVSDAYYILGMSNVLESKEQ
CLFNLKKSYYLLSKEIRDADIEQBARYNLDAKIYFGVKLDEADSRLLLYQKNPTCELSIALQDIIRDRG
DKDFLNYFIACSSDEIECLYDLFYQYFYQANYLFSAIVAKELCNRGDKSLLTQSMVNLGNEKQKGVVDIEE
ISISSLYIINGSNSGIVV

Orf28.1 (not present in γ) (SEQ ID NO:60)

VIIVEFKDRLRQLRRERNLTQHDLGQAIGVTAGSVSKFETGFKPASRETVERAADFLGVPVDYLLGRSDSR
ELDADMNQKYLHIKRNLEQLPBEHQEIVLQNMLTMESLEKLKSTSK

Orf29 (SEQ ID NO:62)

MKVIKDETKLKAAPKSGYKYQELADELEISCSYCYKLNNHNYKKKISYNLASRMAHVLNASVVDLFEEQ
VDFF

Orf30 (SEQ ID NO:64)

MREHRGERAMSEIYYKGFIIKETYGERNIEEVFKEAYESFYGVEVKVVKELGTRNSAAS

Orf31 (SEQ ID NO:66)

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FIGURE 2

MDQLTVASELRLLGRRKVAGYEFTGIEGGFGEKKAMLVLDIATIHNP LKEINRRINDNRIRFKDGV DIV
DLKSGGFNPPQLLNLFPSNMQIAKSNNIYLLSERGYAKLLKILEDDKAWELYDILVDEY FNMREKNQVATD
PMSILKLTFEALEGQQQAIEEIKSDVQDLRENTPLFAIECDEISTAVKRQGVILLGGKQSNAYRNRGLRGK
VYRDIYNQLYREFGVKSHKAIKRCHLNVAVKIVEEYTLPIVLSEEISFVNAQMDFTM

Orf32 (SEQ ID NO:68)

MDQLRVIEGEKVDKPDYVEIYLGAFMNAVNELKKQDEETRSLSKDTYKKAIFYGVRYISISKNDSLNYDYL
MNRFLLSYLENLMKVLTPRDFMTIFPIDKNYDGARYEMKDYFFTMNEIKKIGMDTP IGEKIMEFLWDYQN
FKDITLFNLASVSILNKLQKMGGKTLTEEFAERLGIDTYTKHKEKGGKEYITNDRTGEIQEVKKSRRPYL
KPVQ

Orf33 (SEQ ID NO:70)

MALFRKVHTEFWTDVKVSEDMTPEDKLFMVYLLTNPHTTQLGVYEITPKMIAFEIGLSIESARALLERFEN
HHKLIKYNKLTREIAIKNWGKYNLNRGGKPIEDCLKREIDKVKDLSLIKFILEHTDHAALKRKINLYAGFD
DTSHDTLAI RDQEEKEQKKEQKEEQEEKEKEKEKQKEEKEPEEEKTRIKSKASLKSDAKSNPIPKDIL
DYLNEKANKNFNPKAEGHRKLIRARWNEGYKLEDFKKVIDNKTQWFGKKSFDGKPLDQFLRPSTLFAQKH
FDNYLNETVNISNQHGDDQIVIPGFRGEMPF

Orf34 (SEQ ID NO:72)

VKKIQDSFEKLTCLKFADEQCDKHTFNKHGKEVIKLVKRMIDDAGTVYCPRCMVVEQNSVLFPQANNHYKK
INRRKKNVLFQHSIIENQSITESRLSTYKTDQETKENKEKAIKILERIKNGEFLNVYIAGIQGVGKSHL
AYAMLYELVKHYWVISDGEKLNDHAFKNMKSCLFVEIEKLIRLIQHSFRNIESKYTMDYCI SLMVDVDFL
VIDDLGAESGSMNRNGEASDFVHKILYGV TNGRQGANKTTTTNLSSAQLFQKYDPKLASRLNGVSKDE
TIVFKTTT DKRIVNLDIGF

Orf35 (SEQ ID NO:74)

MKEVKGNKTKLMEEFDVLLRQLLIKSKTDERVKNFLDDLFEMLSDNKLQSDIDFKTALNKLREKHF PKFDK
GESKND

Orf36 (SEQ ID NO:76)

MTKEKGQAKEVVNVRGMSDDFEIEKYGRVLVHHCWVKRYAKKASIERDTGLDIEDLTQFGMIGLIKARDNF
DLEFGCAFSTYAVPKIIGEIGRAIRDNQKIKVQRTVYGVKGKILNQQLADKEPEEADI LDESVS LVKTAL
EYQPSTD SLNKVVYASGANEELTLERMIEDTKTEDIEETTINRAVIREFKAALPPKEYIVLDMRLQNM TQQ
NIANQMGSYQVQISRILAKINQRAAQFGKEGGLQD

Orf37 (SEQ ID NO:78)

LSVTKGVCIDVDHSDLLHEKV EYFLFPAKPSHYVSRFNKGAHFGCYQAERFQITEKEVWTPPEPQPNLPE
LNTSLFYRAQLIWRKKGKDKPLKDYIVQPRGKHCFWHDREK KFCGCFPLHWFTDFVPVQSHHIEEKTR
EEVKLLQRPDGLAFF

Orf38 (SEQ ID NO:80)

MDIKKLFAMQNILDKRVLESKNLSRGEVFEFRILAFDELGECMKEWVVKFWSDDRKPRTSIPTGEIIVL
DDGYEVEVYKNPLLEEYVDGLHFAIGLCIDLKTEINFPASMRCE TVTEQFFELYHLAIRLKEEPTAFRA DV
LLSHYLG LGELLCSLEEIGHEYIEKNKINHERQSNGY

Orf39 (spore surface antigen; replaces 39 in γ) (SEQ ID NO:82)

MDCFKKGKFIFFPCALPIPEAGPTGPTGPPGSAGGSTGPTGPTGPPQLQGIQGVQGNPGTTGPPGIIQGIQ
GIPGVSGPIGPIGPTGIQGVQGIQGFPGIPGPMGPIGLTGPTGIQGIQGIQGVQGIQGIQGDVGPTGPPG
IPGIPGLTGPTGSQGVTVTGPSGGPPGPTGATGPTGPAGGPPGPTGPTGPAGGPTGLTGPTGPTGPTGI
QGIQGVQGTQGIPTGPPGIIQGVQGLQGIPTGIPGSMGPTGLTGPTGLQGIQGIQGNPGPTGPPGPTGPT
GLQGIQGLQGIQGIPTGPNRTPSRNRTS

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FIGURE 2

Orf40 (replaces 40 in γ) (SEQ ID NO:84)

LLAHFPQKLFFFGGTNSGFQRIAGSPGADSDIPYVLGGAGSVVGLSASISINNLPIGVYTIRVCKNVPIN
LAAPGPGQVISTIILTITTAVISGTIILTINPSDIGAQPVRVFNPNLVIAPATVAWSSSTIPGDIVARGDAMS
LFITPGITQNAVYTVFLHTGN

Orf41 (replaces 41 in γ) (SEQ ID NO:86)

MQHIPRYYYQSQSPMDSIWNNNNWIYAWNPYYNYNNNAWNRNPNPCENVRLTDYGARPFVLNINQATKQ
NNTYRTAIWTGKNLQVTLMSINVGGDIGLEVHPTTDQFIRIEEGQLVQMGDNKDKLDFQEMVYDDYAIMI
PAGKWHNVINTGNTPLKRIYAIYAPPEHPYGTVHETKAIAMSTEANRYYY

Orf42 (SEQ ID NO:88)

MIVKATIKLELDDSQKNWVS YVREQGGEEAVFHYLEEEVQKKIELAD FVEMKYKNK

Orf43 (SEQ ID NO:90)

MDMSLVGNLKELOKAIDKVLFEAEEMEIVITKSAASGYSGHRYKIHNNPNRHHMCSKIFIEKLQELLQ
GVKVEFKEEKKNILGGSYYEHYIRFKWND

Orf44 (SEQ ID NO:92)

MTNFKLLKILFWRKGVVERMKTFTNVTFTTELKIYEAVIEAESABKIIDVIKHLKRTEDDLVDKGVINEVSEIN
VSKEQKFE

Orf45 (SEQ ID NO:94)

VNHHLFNWL RDYQKLEED IAYLEYNLDKTKAELRRWVSGDLREVRLTAESGAKVENRIEAI EYELAHKMN
DMYKLLK LISKFRGLENQILKLYVDGMTLEBIEAVNYSSSHIKKHAELVRLIKFVEREGVI

Orf46 (SEQ ID NO:96)

MDVQELSRLENLEHKVLQVETKADVLNRTAIQKGDKIKVVYPHLGIQGEYLVEKIDNGVLELVAETMCK
IQE

Orf47 (SEQ ID NO:98)

LKKLSKQELAAVMTHCISTLGEQIVNEHINPQKLAQASALHNDLFDNTTPKERREATISLLGKAIDEFLES
KE

Orf48 (SEQ ID NO:100)

MGKGYFNKAVCLVCGHQDRVNHPSKKEYQEVTVCPENGA FVDVWKL GKYKRNTQSNEEPLLTITLTDIDA
KPIVHYKGEQIDRKL RVTFDWESQSIDKINRTYIHI EHV PADNKRLNTETIQHNHPIANKEQV

Orf49 (SEQ ID NO:102)

MNGFNKIVNDMQNEQVGNAMLDFALAAKMMFAAFTQFKEAGFNEEQSFELTREILIDSLSKNQ

Orf50 (SEQ ID NO:104)

MQVYCSECDKSYDMQPQVTQLPNRIEKCFFICPHCNHEHIAAYVNDKIRKYQADIAKCHERINKKNLAIED
EMKRLRKRFRDRK

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FIGURE 2

Orf51 (SEQ ID NO:106)

MEGQELTLEKKDSIYLRPRYPHKIDASKIKSLKDVIKILGLMDIRLDDKAVIGLEHLIEKEEE

Orf52 (SEQ ID NO:108)

LKRRKINKMANNKLIIEVTADTTAELEGIKEVTEAANECADALDKLEKIMDKFTNRSDTVELYCEGKLLSKS
TVNHTADSIQCRIIKGEBLGGSER

Orf53 (SEQ ID NO:109)

MKKPLRPCCEFHHCYNLTRERYCEEHRYKEKETQODKNRYYDRFKRDKESTAFYRSKAWERLREQALMRDKG
LCLHCKNNRKIKVADMVDHIIPIKVDPSL
KLKLENLQSLCNPCHNRKTAEDKKKYG

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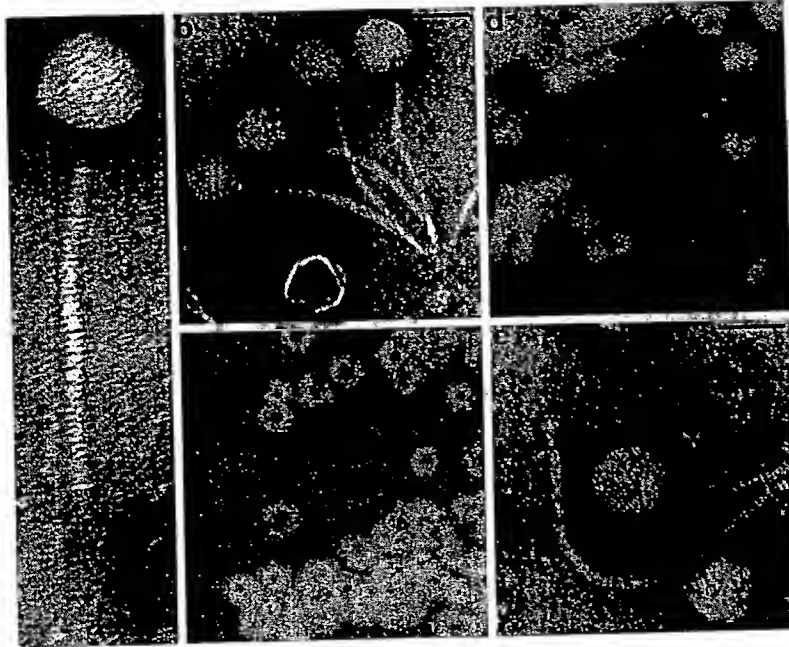
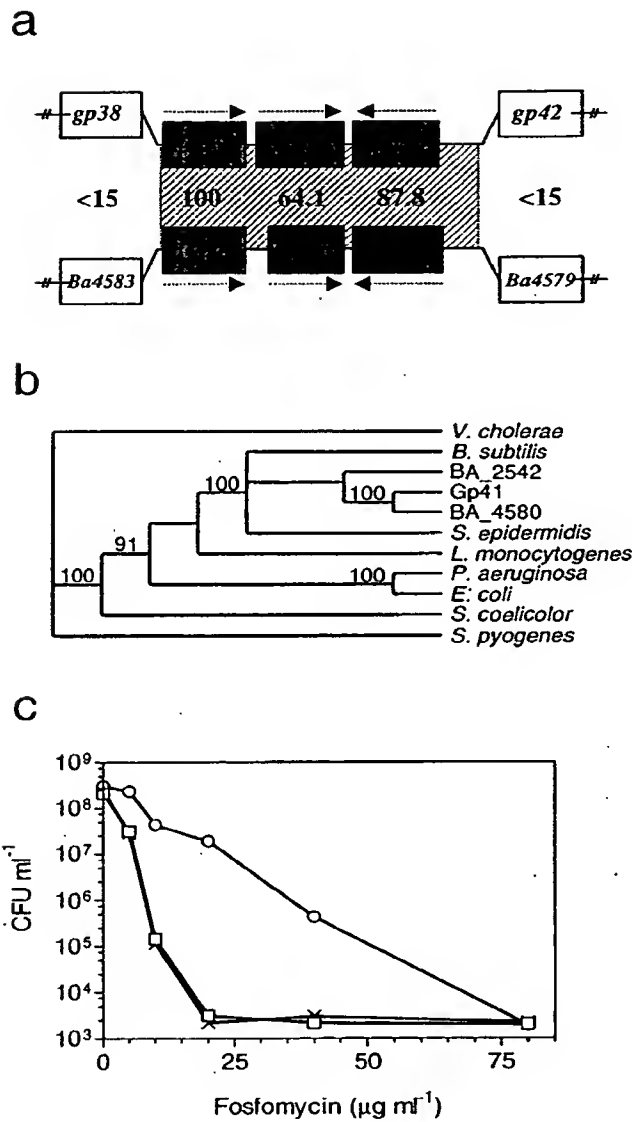


Fig 3

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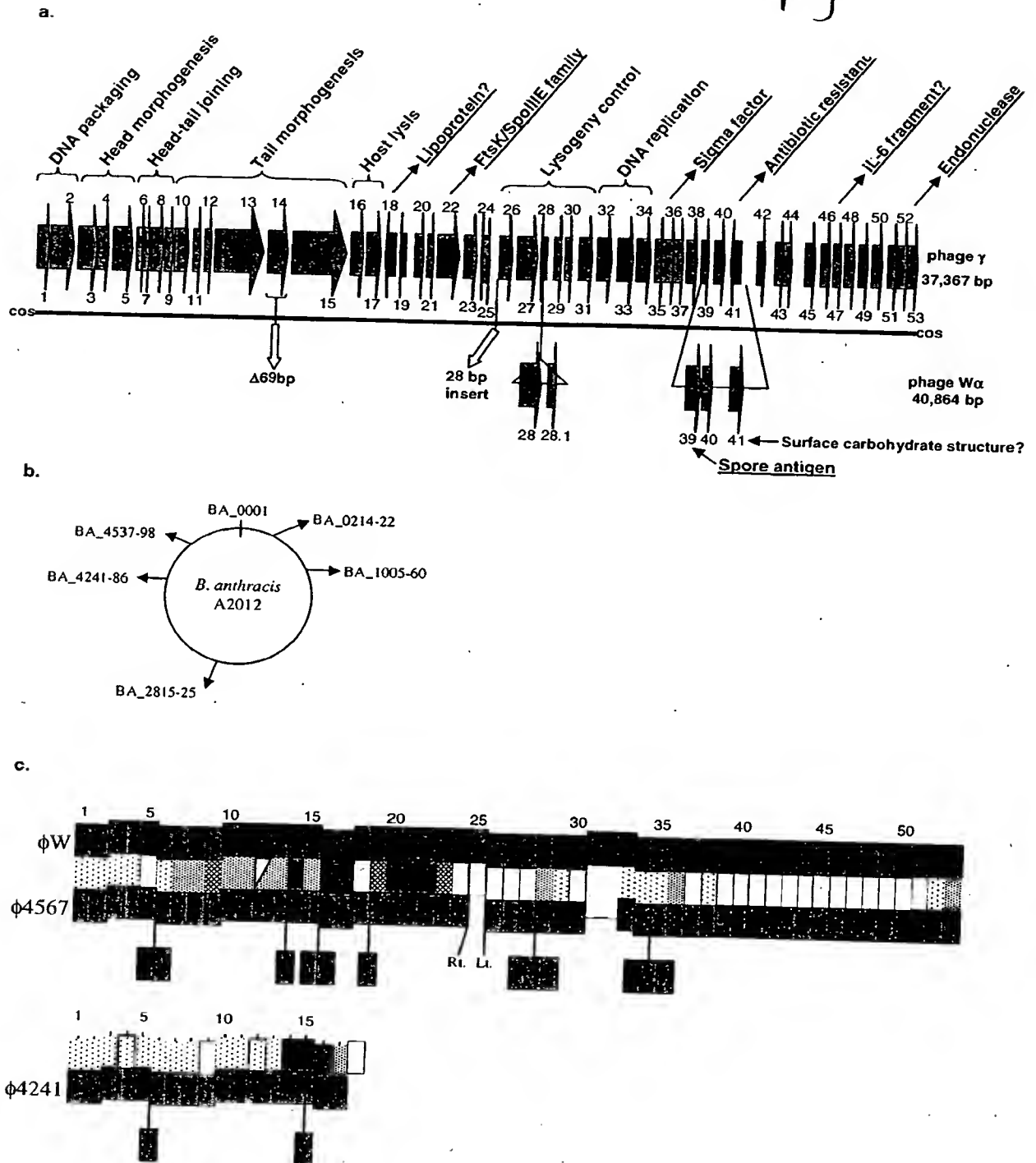
Figure 4



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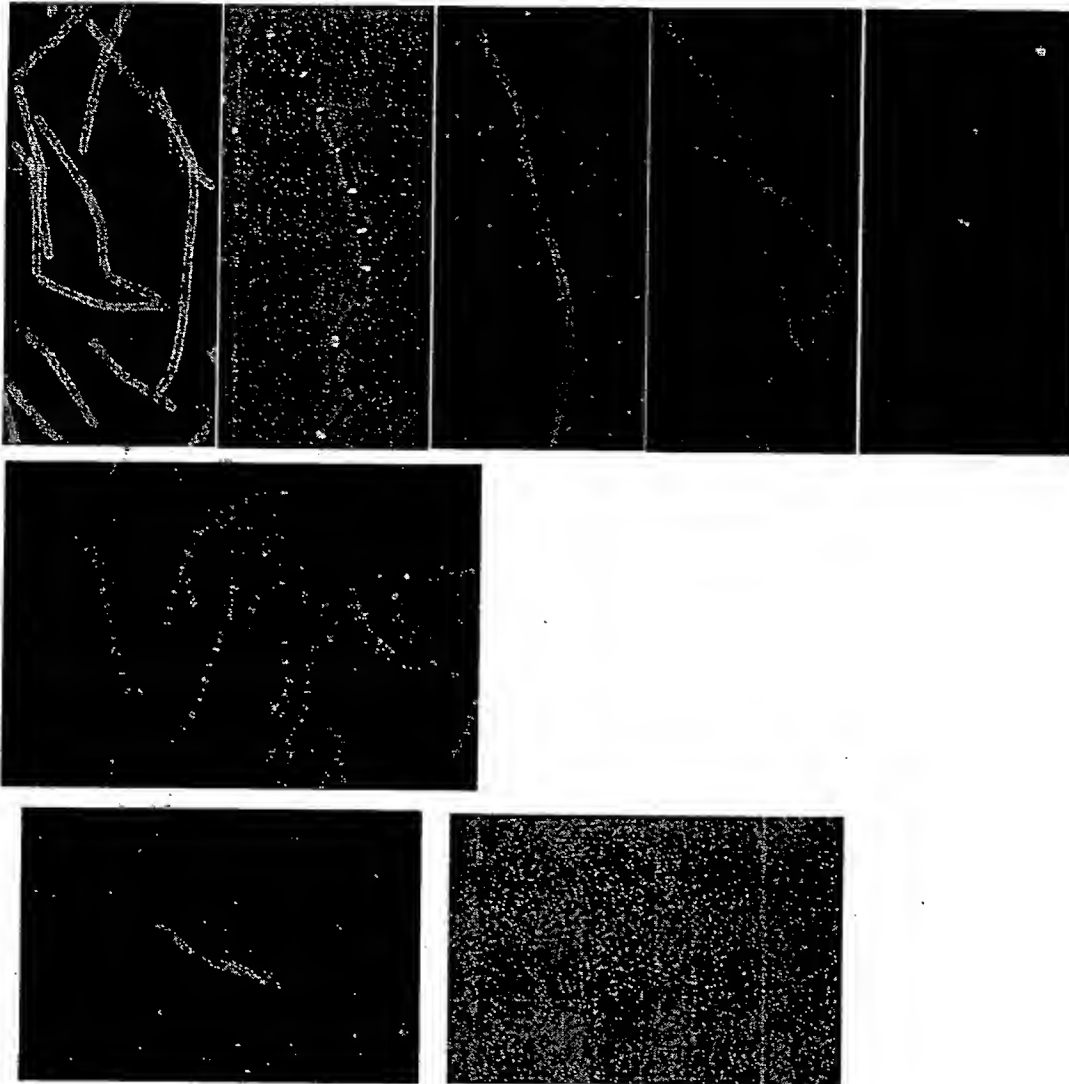
Fig 5



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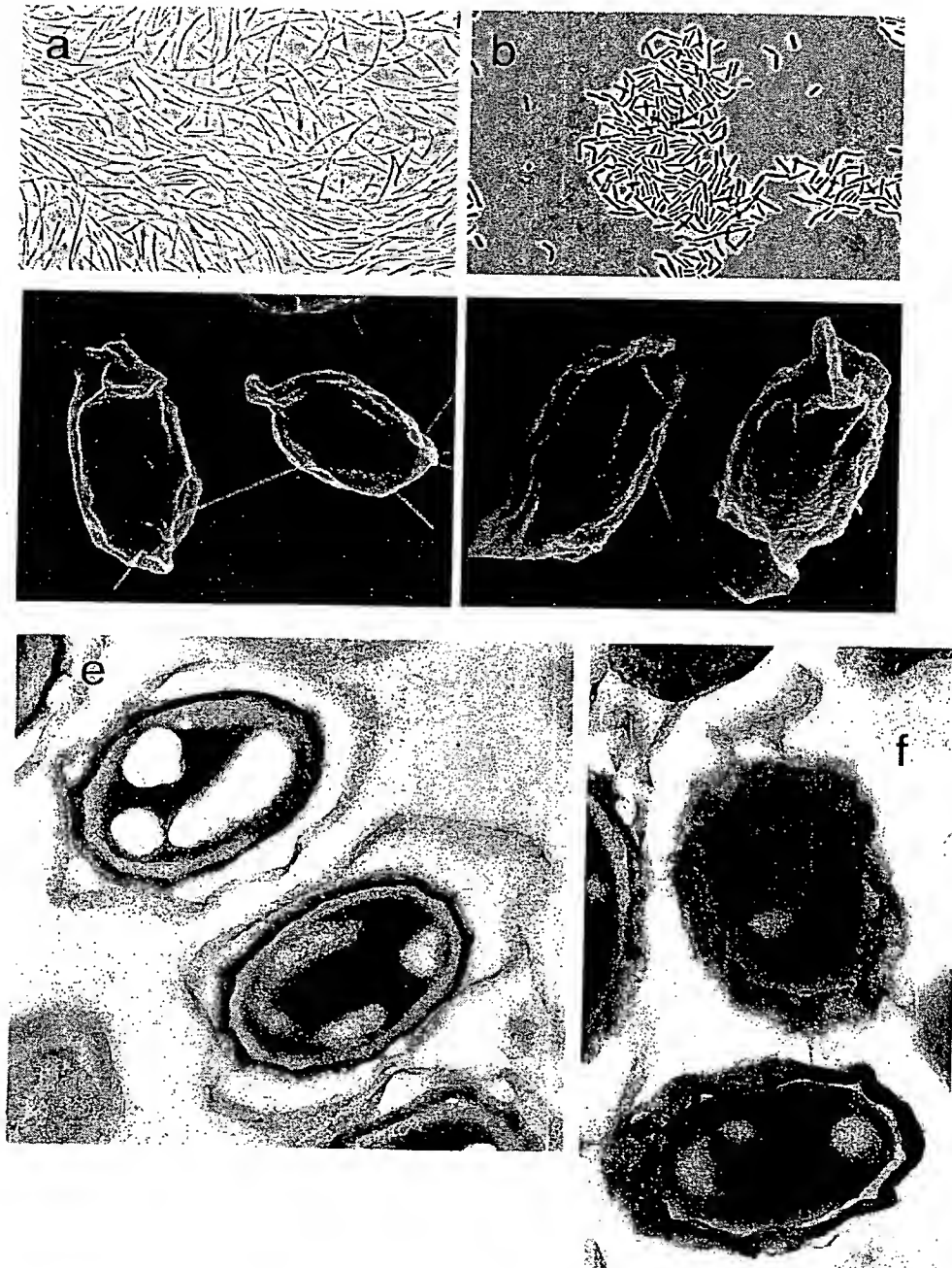
Fig. 6



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Fig. 7



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